FISHERY MANAGEMENT PLAN
for the
SCALLOP FISHERY OFF ALASKA

Prepared by staff of the
National Marine Fisheries Service
North Pacific Fishery Management Council
Alaska Department of Fish and Game

July 1995

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Scallop Management Background

The scallop resource off Alaska has been commercially exploited for almost 30 years. Weathervane scallop stocks off Alaska were first commercially explored by a few vessels in 1967. The fishery grew rapidly over the next 2 years with about 19 vessels harvesting almost 2 million pounds of shucked meat. Since then vessel participation and harvests have fluctuated greatly, but have remained below the peak participation and harvests experienced in the late 1960's. Between 1969 and 1991, about 40 percent of the annual scallop harvests came from State waters. Since 1991, Alaska scallop harvests have increasingly occurred in Federal waters. In 1994, only 14 percent of the 1.2 million lbs landed were harvested in State waters, with the remainder harvested in Federal waters off Alaska.

The State of Alaska has managed the scallop fishery in State and Federal waters, consistent with section 306(a)(3) of the Magnuson Fishery Conservation and Management Act (16 U.S.C. 1801 et seq.)(Magnuson Act), which allows a state to directly regulate any fishing vessel outside state waters if the vessel is registered under the laws of that state. Until 1995, all vessels participating in the Alaska scallop fishery were registered under the laws of the State of Alaska and the fishery was monitored and controlled under State jurisdiction. The North Pacific Fishery Management Council (Council) concluded that the scallop management program implemented by the State provided sufficient conservation and management of the Alaska scallop resource and did not need to be duplicated by direct Federal regulation. Therefore, no Federal regulations were implemented to govern the scallop fishery in Federal waters.

The Council currently is considering options for a fishery management plan for the scallop fishery off Alaska that would authorize a moratorium on vessel entry into the fishery. A vessel moratorium cannot be implemented under Alaska State regulations given existing State statutes. At its April 1994 meeting, the Council requested NMFS to initiate rulemaking to implement a fishery management plan for the scallop fishery off Alaska that would establish a vessel moratorium and defer most other routine management measures to the State of Alaska. The Council was informed that section 306(a)(3) of the Magnuson Act prohibits a state from regulating a fishing vessel in Federal waters unless the vessel is registered under the laws of that state. As a result, routine management measures deferred to the State of Alaska under the Council's proposed management plan could not be applied in Federal waters to vessels not registered with the State. The Council recognized the potential problem of unregistered vessels fishing in Federal waters, but noted that all vessels fishing for scallops in Federal waters were registered under the laws of the State of Alaska. Therefore, the Council recommended that NMFS proceed with implementing the Council's proposed fishery management plan given that all vessels used to fish for scallops off Alaska had been registered with the State and that no information was available to indicate that vessels would not continue to register with the State.

During the period of time that NMFS was developing regulations to implement the Council's proposed management plan, the State of Alaska informed NMFS that a fishing vessel was fishing for scallops in Federal waters of the Prince William Sound management area closed by the State and that the vessel was not registered under the laws of the State. As a result, the vessel operator was not subject to State regulations governing the scallop fishery, including requirements to carry an observer at all times to monitor scallop catch and crab bycatch. The State could not stop this uncontrolled fishing activity because the vessel was not registered with the State of Alaska and was, therefore, operating outside the State's jurisdiction. On February 17, 1995, the Council held a teleconference to address concerns about uncontrolled fishing for scallops in Federal waters by one or more vessels fishing outside the jurisdiction of State regulations and requested that NMFS implement an emergency rule to close Federal waters to fishing for scallops to prevent overfishing of the scallop stocks. Subsequent to the Council's recommendation, the U.S. Coast Guard boarded the vessel fishing for scallops outside the jurisdiction of the State and was informed that 54,000 lbs

of shucked scallop meat was on board. This amount exceeded the State's guideline harvest level for the Prince William Sound area (50,000 lbs) by over 100 percent.

NMFS implemented the emergency rule to close Federal waters off Alaska to fishing for scallops on February 23, 1995 (60 FR 11054, March 1, 1995) to respond to concerns that continued uncontrolled harvest of scallops in Federal waters would result in localized overfishing of the scallop resource. At its February 17, 1995, teleconference, the Council recommended that NMFS should extend the emergency rule for a second 90-day period, through August 28, 1995.

Based on recent events in the scallop fishery that warranted the emergency interim rule, the Council's proposed management plan no longer is an appropriate option for the management of the scallop fishery in Federal waters. Recent participation in the scallop fishery by at least one vessel fishing outside the jurisdiction of the State, contemplation by other vessel owners to fish in Federal waters outside State regulations governing the scallop fishery, and the likelihood that uncontrolled fishing for scallops could occur anywhere off Alaska by the highly mobile scallop processor fleet now requires that Federal regulations be implemented to control scallop fishing activity by vessels that choose not to register with the State of Alaska.

To respond to the need for Federal management of the scallop fishery once the emergency rule expires on August 28, 1995, the Council prepared the proposed Fishery Management Plan for the Scallop Fishery off Alaska (FMP) under section 303 of the Magnuson Act. The FMP would authorize an interim closure of Federal waters to fishing for scallops. The intent of the FMP is to prevent an unregulated and uncontrolled fishery for scallops in Federal waters that could result in overfishing of scallop stocks during the period of time an alternative fishery management plan is prepared that would authorize fishing for scallops under a Federal management regime. The Council pursued this approach because it determined that the suite of alternative management measures necessary to support a controlled fishery for scallops in Federal waters could not prepared, reviewed, and implemented before the emergency rule expires. Instead, the Council prepared the proposed FMP to protect the long-term productivity of scallops stocks off Alaska necessary to support the future harvest of optimum yield on a continuing basis without the "boom and bust" syndrome that other scallop fisheries historically have portrayed.

A description of the scallop fishery off Alaska, as well as harvest amounts and the number of vessels annually participating in the fishery is presented in Appendix A.

1.2 Description of the Management Area and Habitat

1.2.1 Geographic description of the management area

The management areas covered under the FMP includes all Federal waters of the Gulf of Alaska (GOA) and the Bering Sea/Aleutian Islands area (BSAI). The GOA is defined as the U.S. exclusive economic zone (EEZ) of the North Pacific Ocean, exclusive of the Bering Sea, between the eastern Aleutian Islands at 170°W longitude and Dixon Entrance at 132°40'W longitude. The BSAI is defined as the U.S. EEZ south of the Bering Strait to the Alaska Peninsula and Aleutian Islands and extending south of the Aleutian Islands west of 170° W long.

1.2.2 Physical habitat

The continental shelf parallels the southeastern Alaska coast and extends around the GOA. Total area of continental shelf in the GOA is about 160,000 square km, which is more than the shelf area in the Washington-California region but less than 25 percent of the eastern Bering Sea Shelf. Between Canada and Cape Spencer the Continental Shelf is narrow and rough. North and west of Cape Spencer it is broader.

Although its width is less than 10 miles at some points, it is generally 30 to 60 miles wide. As it curves westerly from Cape Spencer towards Kodiak Island it extends some 50 miles seaward, making it the most extensive shelf area south of the Bering Sea. West of Kodiak Island and proceeding along the Alaska Peninsula toward the Aleutian Islands, the shelf gradually becomes narrow and rough again. More detailed information on the Alaskan shelf can be found in Sharma (1979).

Coastal waters overlying the continental shelf are subject to considerable seasonal influences. Winter cooling accompanied by turbulence and mixing due to major storms results in a uniform cold temperature in the upper 100 m. Seasonal changes in temperature and salinity diminish with increasing depth and distance from shore. Along the outer shelf and upper slope, bottom water temperatures of 4 to 5° C persist year-round throughout the periphery of the GOA. With further increase in depth, water temperature shows no significant seasonal change but gradually decreases with depth, reaching 2° C or less at greater depths. The water circulation pattern in both the eastern Bering Sea and Gulf of Alaska is a counterclockwise gyre (Sharma 1979). Inshore current flow patterns are affected by weather, tides, and topography.

All commercial fisheries for Alaskan scallops take place in relatively shallow waters (< 200 m) of the continental shelf. Weathervane scallops are found at depths ranging from intertidal waters to depths of 300 m (Foster 1991), but abundance tends to be greatest between depths of 45-130 m on substrates consisting of mud, clay, sand, or gravel (Hennick 1973). Although weathervane scallops are widely distributed along the shelf, the highest densities in Alaska have been found to occur in discrete areas. Areas fished during the 1993 scallop fishery included beds in the Bering Sea, off the Alaska Peninsula, in Shelikof Strait, on the east side of Kodiak Island, and along the Gulf coast from Yakutat to Kayak Island (Figure 1). Testimony from fishermen indicate that the Kodiak stocks are currently depressed.

The distribution of scallop beds is thought to be greatly affected by depth, bottom type, and ocean current patterns (NEFMC 1982). Variation in current patterns, along with other abiotic and biotic factors, likely affect local recruitment and distribution. The location of scallop beds depends on the speed and direction of those currents, as larvae are pelagic, and drift with the currents for several weeks before settling. Scallop beds tend to be elongated along the direction of current flow, and aggregations often represent different age or size groups (Caddy 1989; Robert and Jamieson 1986).

1.2.3 Benthic community

In both the Bering Sea and Gulf of Alaska, scallops are only a part of a diverse benthic community. Besides scallops, several other species of invertebrates are commercially harvested off Alaska, including clams, crabs, octopus, squid, and shrimp. Commercially important crab species include red king crab (Paralithodes camtschatica), blue king crab (P. platypus), brown or golden king crab (Lithodes aequispina), dungeness crab (Cancer magister), and two species of Tanner crab (Chionoectes bairdi, and C. opilio). Distribution of these species in the Bering Sea and Aleutian Islands is shown in Figure 2, and summarized by Otto (1981) and Lewbel (1983). Red king crabs are distributed from Southeast Alaska to Kodiak Island and northward into Norton Sound, with highest densities at depths of 40-100 meters. Blue king crabs also occur at those depths, but are distributed primarily around the Pribilof, St. Matthew, and St. Lawrence Islands. Tanner crabs occur at those depths, and deeper to 700 meters. C. opilio are distributed throughout the Bering Sea. C. bairdi, on the other hand, are distributed through the Gulf of Alaska and Aleutian Islands to the Bering Sea, with highest concentrations in the Bering Sea from the Alaska Peninsula to the Pribilof Islands. A summary of life history information for crabs is provided by Adams (1979), Somerton (1981), and Kessler (1985). Fisheries information for king and Tanner crabs can be found in the following references: Browning (1980), Otto (1981), and NPFMC (1989).

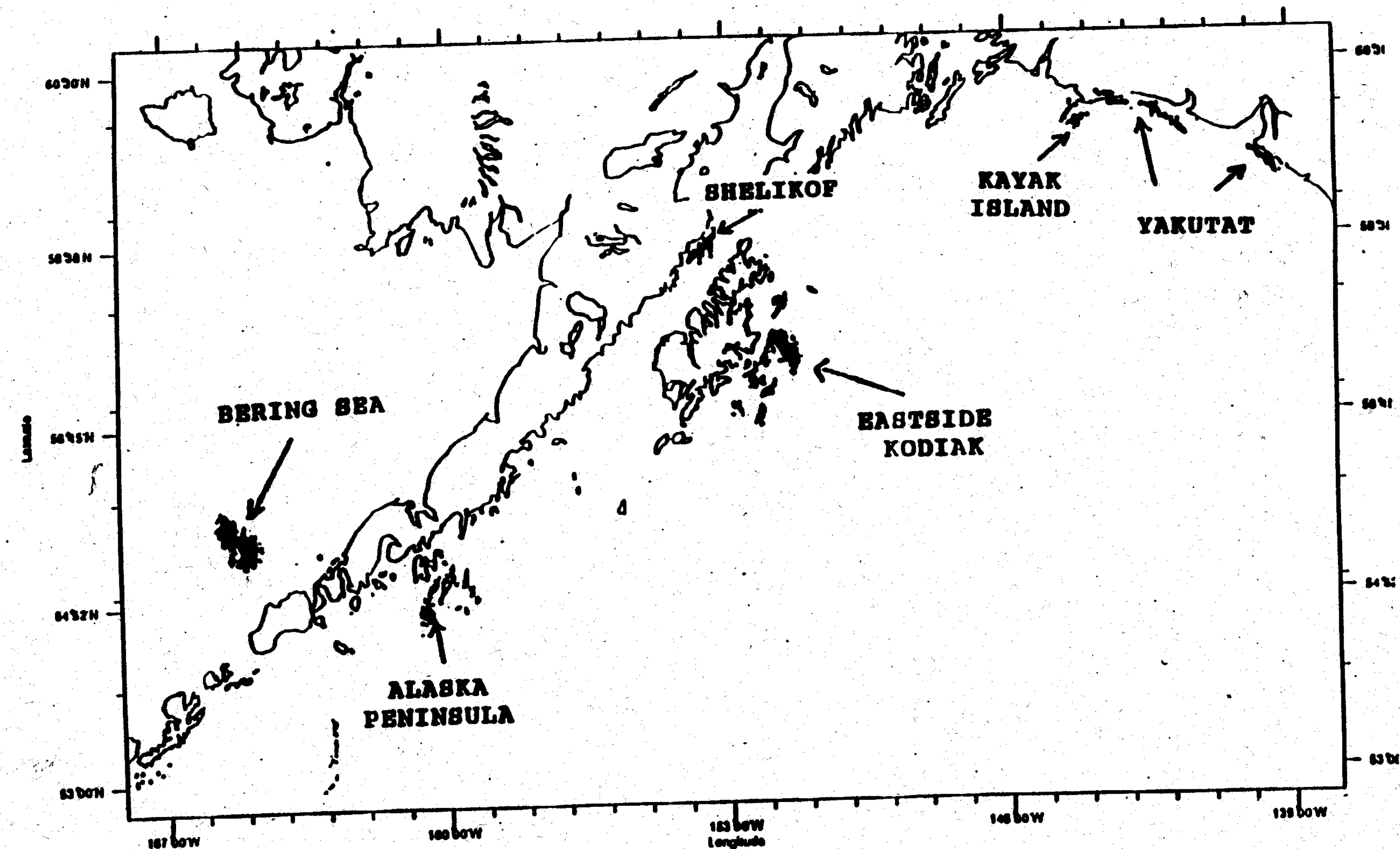

Figure 1 Areas fished statewide during the 1993 scallop fishery. Fishing in Southeast Alaska and parts of Dutch Harbor are remain confidential. From Urban et al. (1994).

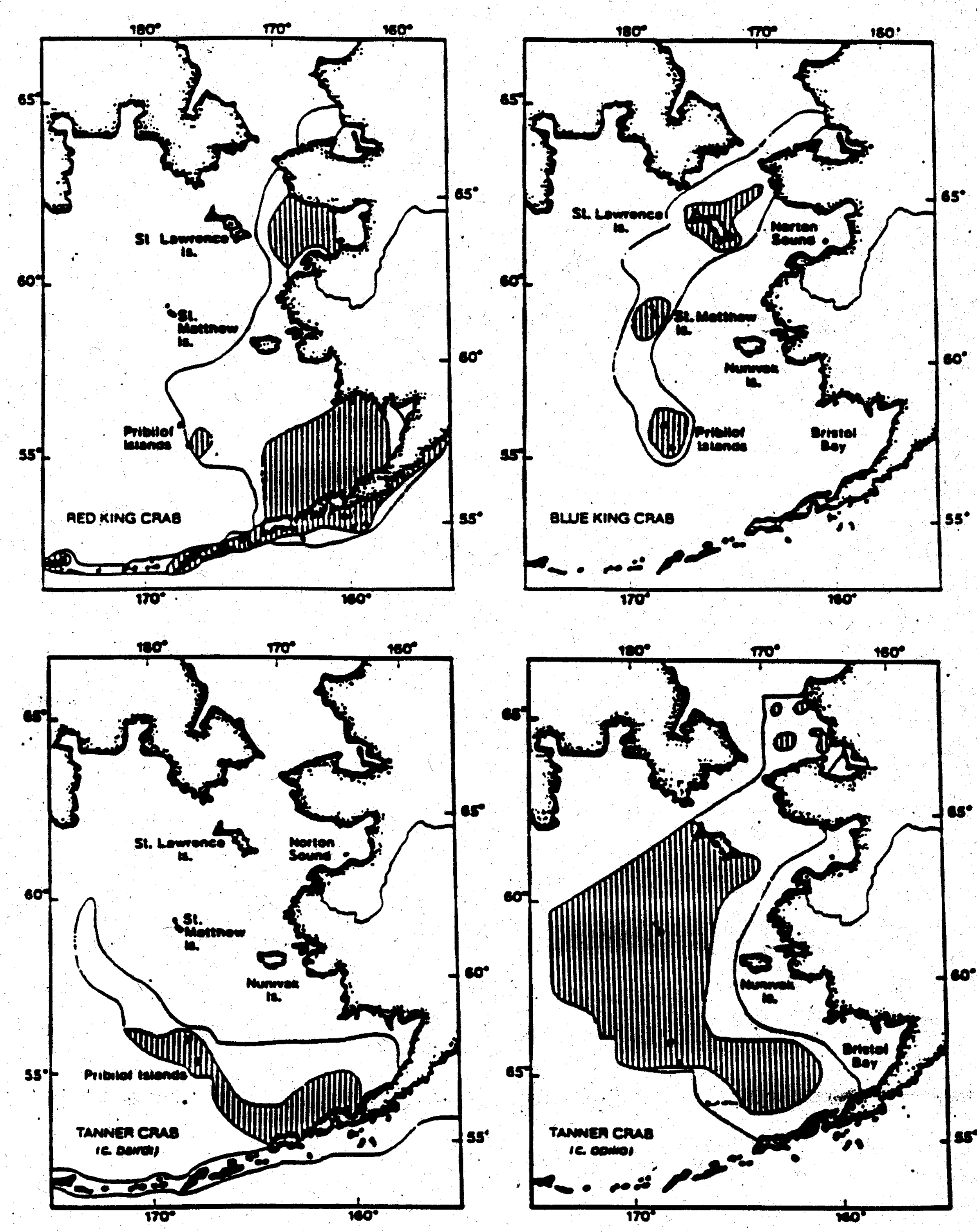

Figure 2 Distribution of king and Tanner crabs off the Bering Sea and Aleutian Islands. Areas of highest crab density are shown by vertical bars. From Otto (1981).

In addition to a crab fishery, there also large fisheries for groundfish using pot, longline, jig, and trawl gear. Fisheries for groundfish target walleye pollock (Theragra chalcogramma), Pacific cod (Gadus macrocephalus), lingcod (Ophiodon elongatus), sablefish (Anoplopoma fimbria) Atka mackerel (Pleorogrammus monopterygius), Pacific ocean perch (Sebastes alutus) and other rockfish species, and numerous species of flounder. In the Bering Sea yellowfin sole (Limanda aspera) dominates the flounder community, but is comparatively scarce in the Gulf and absent off Washington-California. The arrowtooth flounder, (Atheresthes stomias), is widely distributed along the Pacific and Bering Sea coasts of the United States and appears to comprise the largest part of the exploitable biomass of flounders in the Gulf of Alaska. Other abundant flounders in the Gulf include Pacific halibut (hippoglossus stenolepis), which reaches its greatest abundance there and off British Columbia; rocksole (Lepidopsette bilineata); starry flounder (Platichthys stellatus); flathead sole (Hippoglossoides elassodon); rex sole (Glyptocephalus zachirus); and, in deep water, Dover sole (Microstomus pacificus). Pacific salmon (Oncorhynchus sp.), and herring (Clupea pallasii) tend to be of a pelagic nature. A more complete description of commercial groundfish, other finfish, and shellfish stocks can be found in the Council's annual Stock Assessment and Fishery Evaluation report for the groundfish stocks (NPFMC 1994b) and several plan amendment analyses (e.g., Amendment 18/23, NPFMC, 1992).

Scallops also share the benthic habitat with non-economically important fish and invertebrate species. Non-commercial fishes include skates, sharks, sculpins, and numerous species of small fishes. Large invertebrates not usually commercially harvested generally include some crab and shrimp species, snails, clams, worms, jellyfish, seasquirts, bryozoans, sea urchins, seastars, sea anemones, sponges, corals, and many others. Various types of corals inhabit the Gulf of Alaska, including fan corals, bamboo corals, cup corals, soft corals, and hydrocorals (Cimberg et al. 1981). Generally, corals do not have the same habitat requirements as scallops and occur at greater depths than scallops. Two of the more abundant species in waters less than 100 fathoms are red tree (Primnoa willeyi) and sea raspberry (Eunephtya sp). These species occur in areas of rugged habitat consisting of boulders and bedrock, habitats that are not inhabited by most scallop species.

1.2.4 Vulnerability to pollution

Scallop populations are vulnerable to pollution, even in offshore habitats where ocean dumping and runoff can have an effect (Gould and Fowler 1991). Ocean dumping of sediments may bury or damage scallops by abrasion and gill clogging (Larsen and Lee 1978). Nutrient loading can cause a low dissolved oxygen (hypoxic) conditions (Sindermann 1979), and an increase in bacterial infections (Leibovitz et al. 1984), or algal (Wassman and Ramus 1973) and dinoflagellate blooms (Shumway 1990), all of which can be detrimental to scallop populations. Naturally occurring toxins, such as that from the dinoflagellate Gonyaulax catenella, concentrate in exposed scallops, and incidence of paralytic shellfish poisoning (PSP) from eating scallops have been documented (Hudgins, 1981).

Scallops can also be affected by oil spills, via decreased gill respiration, but the effects are considered to be short-lived (Gould and Fowler 1991). Spiny scallops were found to be moderately sensitive to acute exposures (96 hour) to Cook Inlet crude and No. 2 fuel oil (Rice et al. 1979). Drilling muds are also of concern, in that they release sediments and heavy metals. Metals also are released by dumping, and municipal and industrial water discharges. Scallops are efficient at concentrating PCBs and heavy metals, including silver, copper, and nickel (Pesch et al. 1979), mercury (Klein and Goldberg 1970), cadmium (Vattuone et al. 1976), chromium (Mearns and Young 1977). At certain levels of concentration, heavy metals can be lethal or have adverse effects at lesser concentrations. Sublethal concentrations of copper produced substantial kidney and gonad damage in sea scallops, whereas cadmium induced hormonal changes such as early gonad maturation in sea scallops (Gould et al. 1985).

Because of their affinity for uptake of trace metals, sea scallops are readily contaminated in areas of ocean

dumping making their marketable meats and gonads unacceptable for human consumption. Contamination of scallop beds by trace metals can cause adult scallop mortality and can affect the reproductive physiology of sea scallops, thus increasing the probability of poor recruitment (NEFMC 1993).

Measures to protect scallop habitat should be taken based on the concerns mentioned above. The dumping of dredge spoils, drilling muds, and municipal and industrial wastes should be minimized in areas of known scallop concentrations. Dispersal by water currents should also be taken into account when waste disposal and drilling sites are chosen.

1.3 Biological and Environmental Characteristics of the Resource

1.3.1 Description and distribution

The weathervane scallop (Patinopecten caurinus), is a bivalve and classified by having a single adductor muscle, a socket-like hinge, and distinct dorsal and ventral valves. Scallops have a limited swimming ability by utilizing hydraulic water pressure achieved by clapping the valves together. Numerous eyes, or ocelli, are located along the outer mantle on stalks. Scallops are non-burrowing filter feeders, subsisting primarily on phytoplankton.

Weathervane scallops are distributed from Point Reyes, California, to the Pribilof Islands, Alaska. The highest known densities in Alaska have been found to occur off Kodiak Island and along the eastern gulf coast from Cape Spencer to Cape St. Elias. Weathervane scallops are found from intertidal waters to depths of 300 m (Foster 1991), but abundance tends to be greatest between depths of 45-130 m on beds of mud, clay, sand, and gravel (Hennick 1973). Similar to patterns documented for other scallop species (Caddy 1989; Robert and Jamieson 1986), beds are elongated along the direction of current flow, and aggregations often represent different age or size groups.

Although the weathervane scallop has been the principal commercial species off Alaska, several other species of scallop found in the EEZ off Alaska have commercial potential. These scallops, thought to be closely related to the Icelandic scallops (Chlamys islandica) of the North Atlantic, grow to smaller sizes than weathervanes, and thus have not been extensively exploited in Alaska. Chlamys behringiana inhabit the Chukchi Sea to the Western Bering Sea. Chlamys albida are distributed from the Bering Sea and Aleutian Islands to the Japan Sea. Pink scallops, Chlamys rubida, range from California to the Pribilof Islands. Spiny scallops, Chlamys hastata, are found in coastal regions from California to the Gulf of Alaska.

Little is known about the biology of these scallop species. Chlamys species occupy different habitats and have different growth characteristics than weathervanes. Pink scallops are found in deep waters (to 200 m) in areas with soft bottom, whereas spiny scallops occur in shallower (to 150 m) areas characterized by hard bottom and strong currents. Spiny scallops grow to slightly larger sizes (75 mm) than pink scallops (60 mm). Both species mature at age 2, or about 35 mm, and are characterized by high natural mortality, with maximum age of about 6 years. Spiny scallops are autumn spawners (August-October), whereas pinks are winter spawners (January-March) (Bourne and Harbo 1987).

Rock scallops, Crassadoma gigantea, range from Mexico to Unalaska Island. The abundance of this species is not known, and a commercial fishery has never been developed. Because they attach themselves to rocks, trawls and dredges are not efficient in capturing rock scallops. As suggested by the species name, these scallops attain a large size (to 250 mm) and exhibit fast growth rates. Rock scallops are found in relatively shallower water (0-80 m) with strong currents. Apparently, distribution of these animals is discontinuous, and the abundance in most areas is low. Rock scallops may spawn during two distinct periods, one in the autumn (October -January), and one in the spring-summer (March-August) (Jacobsen 1977).

1.3.2 Reproduction and early life history

For weathervanes and the other scallop species, sexes are separate although one case of hermaphroditism in weathervanes has been observed (Hennick 1971). Mature male and female scallops are distinguishable: female gonads are pink or orange-red whereas gonads of males are white (Haynes and Powell 1968; Robinson and Breese 1984). Although spawning time varies with latitude and depth (Robinson and Breese 1984; MacDonald and Bourne 1987; Starr and McCrae 1983), weathervane scallops in Alaska appear to mature in mid-December to late January and spawn in May to July depending on location (Hennick 1970a).

Scallops develop through egg, larval, juvenile, and adult life stages (Figure 3). Eggs and spermatozoa are released into the water, where the eggs become fertilized (Cragg and Crisp 1991). After a few days, eggs hatch, and larvae rise into the water column and drift with ocean currents. Larvae are pelagic and drift for about one month until metamorphosis to the juvenile stage (Bourne 1991). The "post-larvae" settle and attach to a hard surface on the bottom with strings called "byssal threads". Young juveniles may remain attached, or they may become mobile by use of a "foot", or they may swim. Within a few months the shell develops pigmentation, and juveniles then resemble the adult in appearance.

Weathervane scallops mature by age 3 at about 7.6 cm (3 inches) in shell height (SH), and virtually all scallops are mature by age 4 (Haynes and Powell 1968; Hennick 1970b, 1973). Growth is most rapid during the first 10-11 years (Hennick 1973). However, growth, maximum size, and size at maturity vary significantly within and between beds and geographic areas. For example, on average, maximum size as measured by (SH), tends to be about 190 mm (7.5 inches) SH for Marmot Flats off Kodiak Island and only 144 mm (5.7 inches) SH for the Cape Fairweather - Cape St. Elias area. The largest recorded specimen measured 250 mm (9.8 inches) SH and weighed 340 g (12 ounces, Hennick 1973). Although increasing with age and size, weight varies seasonally; meat yield declines during the spawning season and increases during the growing season. In addition, adductor weights of weathervane scallops apparently vary among regions, with the west side of Kodiak Island producing the largest meats relative to shell size.

1.3.3 Longevity and natural mortality

Weathervane scallops are long-lived; individuals may live 28 years old or more (Hennick 1973). The natural mortality rate (M) is thought to be low, although estimates vary. Based on a 28 year maximum life span, M is estimated to be 0.16 using Hoenig's (1983) equation. Similar estimates of mortality are obtained by applying catch curves to Hennick's (1973) data from the commercial fishery; resulting rates are 0.13, 0.16, 0.16 for Yakutat, westside Kodiak, and eastside Kodiak respectively (G. Kruse, ADF&G, personal communication). The Atlantic sea scallop, <u>Plactopecten magellanicus</u>, which exhibits a life history pattern similar to weathervanes, has a relatively low natural mortality rate, as M=0.10 (Medcof and Bourne 1964). Little is known about the causes of natural mortality for scallops. Scallops are likely prey to various fish and invertebrates during the early part of their life cycle. Flounders are known to prey on juvenile weathervane scallops, and seastars may also be important predators (Bourne 1991).

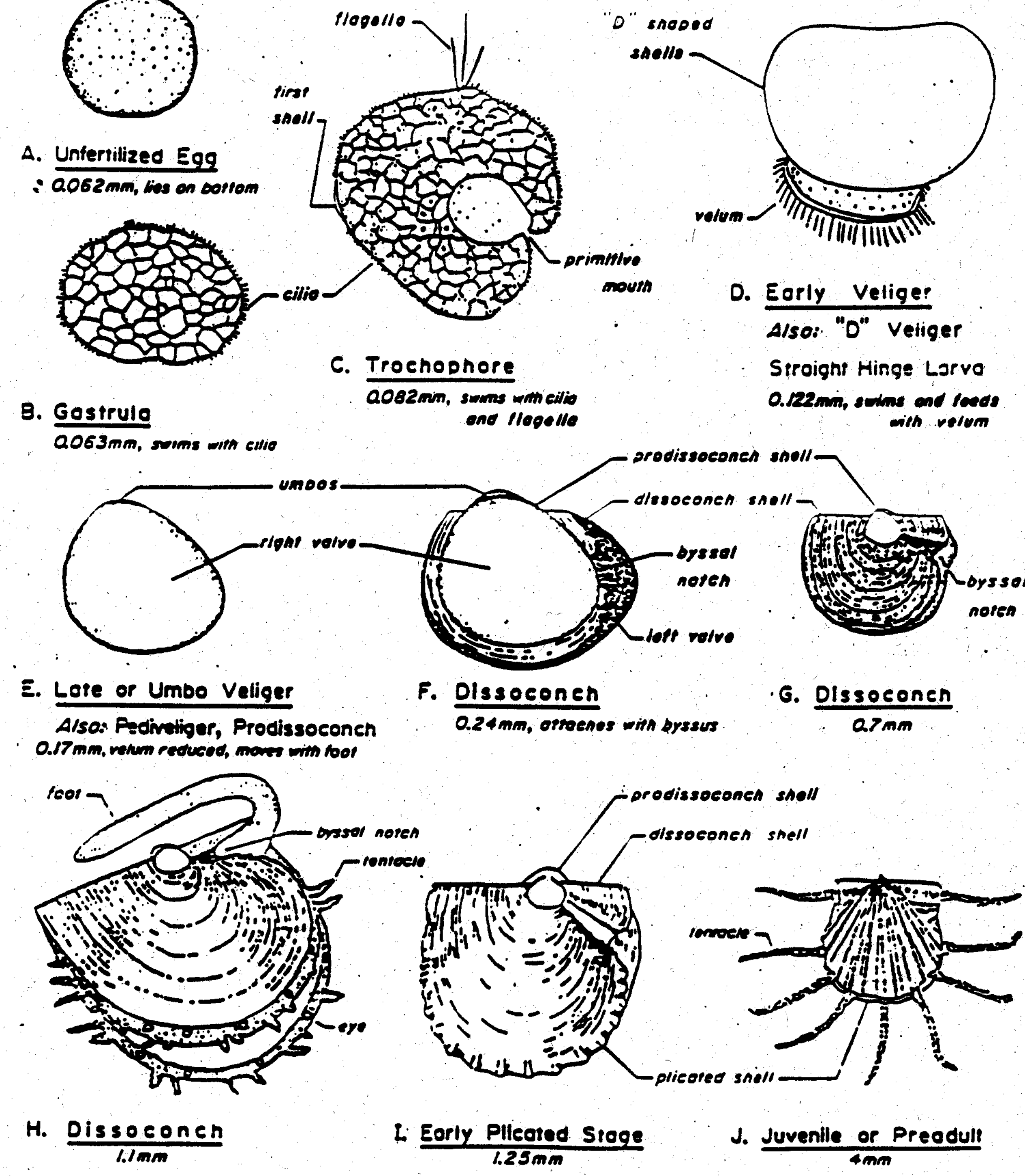

Figure 3. Larval and juvenile stages of the scallop. Bottom (right) valve is shown uppermost in E-J.

Source: Mottet 1979.

1.3.4 Stock structure and productivity

The stock structure of weathervane scallops has not been studied. Until recently, benthic ecologists generally believed that invertebrate species generally have "open" populations that are well-connected to other, geographically-distinct populations by advection of pelagic larvae. Growing evidence exists, however, that some invertebrate populations are actually comprised of multiple discrete, self-sustaining populations (Sinclair 1988; Orensanz et al. 1991). Sinclair et al. (1985) suggested that three species of scallops in the North Atlantic Ocean were comprised of a number of discrete, self-sustaining populations. From Virginia to Newfoundland, at least 19 discrete concentrations of Atlantic scallops may be self sustaining populations (Sinclair 1988). Fevolden (1989) provided strong evidence for restricted gene flow among different concentrations of Iceland scallop (Chlamys islandica) in the northeast Atlantic Ocean and concluded that scallops sampled from different areas of the northeast Atlantic Ocean should be treated as discrete genetic units for management purposes. Last, Caddy (1989) asserted that it is reasonable to assume that historically-maintained centers of scallop concentrations are self-sustaining populations. Further, he recommended that these commercially-important scallop beds should compose the unit stock upon which management measures are based. He also noted that a scallop fishing ground may contain several beds of high scallop density that are surrounded by a number of low-density scallop fishing areas.

Only limited information on biological productivity is available for weathervane scallops to promote the conservation of stocks and sustained yield of the fishery. Much of this information (Haynes and Powell 1968; Hennick 1970b, 1973) was collected during the early years of the fishery, but has been summarized more recently by Kaiser (1986). Although the fishery has been prosecuted every year since 1967 except 1978, the only assessment survey since 1972 was conducted in 1984 in lower Cook Inlet (Hammarstrom and Merritt 1985). Total scallop biomass in the Yakutat and Kodiak area ranged from 12,335 to 17,445 tons (Ronholt et al. 1977), but these estimates were based on inefficient shrimp trawls and were considered by Kaiser (1986) to be a minimum biomass estimate. A population of weathervanes in the Gulf Islands area of southern British Columbia was estimated to have a density of about 1 scallop per 65 square meters (Bourne 1991). In addition to a lack of good abundance estimates, there have been no routine biological or fishery sampling programs conducted on weathervane scallops. A new observer program, instituted in July 1993 by the State of Alaska, may provide better abundance information. The distribution of scallops in Alaskan waters is rather well-known, but insufficient information on abundance, exploitation rates, recruitment, and other key population dynamics parameters hampers fishery management based on population dynamics.

1.4 Alaska State Management of the Scallop Fishery

1.4.1 Current State management regime

The primary pectinid harvested off Alaska is the weathervane scallop (Patinopecten caurinus). Since the early 1980's, between 4 and 20 vessels annually have participated in the Alaska scallop fishery. Gross earnings experienced by the fleet during this same period of time has ranged from almost $.9 million in 1983 to about $7 million in 1992. Between 1969 and 1991, about 40 percent of the annual landings of scallops from waters off Alaska were comprised of scallops harvested from State waters. Since 1991, however, scallop harvests have increasing occurred in Federal waters. In 1994, only 14 percent of the scallop landing came from State waters, with the remainder harvested in Federal waters off Alaska (Table 1). The State of Alaska has managed the scallop fishery in State and Federal waters, consistent with section 306(a)(3) of the Magnuson Fishery Conservation and Management Act (16 U.S.C. 1801 et seq.), which allows a state to directly regulate any fishing vessel outside state waters if the vessel is registered under the law of that state.

Table 1. Percentage of Alaska scallop landings from State (within 3 miles) and Federal waters (3-200 miles), by year from 1990 through 1994 (Ken Griffin, ADF&G, personal communication).

Year	State Waters	Federal waters
1990	46.9%	53.1%
1991	37.9%	62.1%
1992	73.6%	26.4%
1993	23.9%	76.1%
1994	13.7%	86.3%

The Alaska Department of Fish and Game (ADF&G) initiated development of a management plan for the scallop fishery in response to overfishing concerns resulting from recent changes in the weathervane scallop fishery off Alaska. Weathervane scallops possess biological traits (e.g., longevity, low natural mortality rate, and variable recruitment) that render them vulnerable to overfishing. Record landings occurred in the late 1960's (about 1.8 million pounds shucked scallop meat), followed by a significant decline in catch through the 1970's and 1980's when landed catch ranged between 0.2 and 0.9 million pounds. The ADF&G believes this decline is due, in part, to reduced abundance of scallop stocks (Kruse, 1994). Landings since 1989 have increased to near record levels. During this period, the number of vessels fishing for scallops has not increased (about 10 - 15 vessels annually), although an increase in fishing power is evidenced by a substantial increase in average vessel length (from 84 feet registered length in 1981 to 110 feet in 1991), a predominance of full-time scallop vessels, and an increased number of deliveries. Until 1993, the State did not have a data collection program, although some indication exists that overfishing, or at least localized depletion may have occurred. Data voluntarily submitted by participants in the scallop fishery during the early 1990's showed that an increase in meat counts per pound has occurred, indicating that smaller scallops now account for a greater proportion of the harvest. These data also suggest that catch per unit of effort in traditional fishing grounds has decreased.

Limited age data suggest that the scallop stock historically exploited off west Kodiak Island experienced an age-structure shift from predominately age 7 and older scallops in the late 1960's to an age structure predominated by scallops less than age 6 during the early 1970's. This shift indicated that harvest amounts had exceeded sustainable levels. Changes in fleet distribution from historical fishing grounds primarily in State waters to previously unfished grounds in the EEZ compounded management concerns.

In response to these concerns, the ADF&G implemented a management plan for the scallop fishery in 1993-94 that established a total of nine fishery registration areas corresponding to the Southeastern, Yakutat, Prince William Sound, Cook Inlet, Kodiak, Alaska Peninsula, Dutch Harbor, Adak, and Bering Sea portions of the State. To prevent overfishing and maintain reproductive potential of scallop stocks, ADF&G established a guideline harvest range (GHR) for each of the traditional weathervane scallop fishing areas. In the absence of biomass estimates needed to implement an exploitation rate harvest strategy, the upper limit of the GHRs are specified as the long-term productivity (catch) from each of the traditional harvest areas. The ADF&G may adjust GHRs based on changes in stock status, such as shifts in population size/age structure coupled to changes in area-specific catch-per-unit-effort. If a GHR for a registration area is not specified, ADF&G may authorize fishing for weathervane or other scallop species under special use permits that generally include location and duration of harvests, gear limitations and other harvest procedures, periodic reporting or logbook requirements, requirements for onboard observers, and scallop catch or crab

bycatch limits.

The ADF&G also has implemented king and Tanner crab bycatch limits to constrain the mortality of Tanner crab and king crab incidentally taken by scallop dredge gear. Generally, crab limits are set at 1 percent of total crab population for those management areas where crab stocks are healthy enough to support a commercial fishery. In areas closed to commercial fishing for crab, the crab bycatch limits for the scallop fishery are set at 0.5 percent of the total crab population.

Specified waters are closed to fishing for scallops to prevent scallop dredging in biologically critical habitat areas, such as locations of high bycatch of crab or nursery areas for young fish and shellfish. State regulations also require each vessel to carry an observer at all times to provide timely data for monitoring scallop catches relative to GHRs and for monitoring crab bycatch. Observers also collect scientific data on scallop catch rates, size distribution and age composition. This information is required by ADF&G for potential adjustment of GHRs based on changes in stock status and productivity.

Last, ADF&G regulations establish gear specifications to minimize the catch of undersized scallops and efficiency controls to reduce the economic feasibility of harvesting scallops much smaller than sizes associated with optimum yield. Current efficiency controls include a ban on automatic shucking machines and a crew limit of 12 persons.

The 1995 scallop guideline harvest levels and crab bycatch limits, as well as 1994 - 1995 scallop harvest and crab bycatch amounts in each State registration area opened for harvest in 1994-95 are listed in Table 2. In 1994, vessels fished for scallops in the Bering Sea and Alaska Peninsula registration areas under special-use permits. These areas were closed in late summer due to crab bycatch. The 1994 scallop fisheries in other registration areas generally were closed based on the attainment of the guideline harvest level (GHL) (Table 2).

1.4.2 Impact of Federal regulations on State management activities

Under the FMP, regulations that close Federal waters to fishing for scallops could displace fishing effort into State waters, which may remain open to fishing for scallops under State regulations. A closure of Federal waters will be implemented in consultation with the Commissioner of the ADF&G so that the State may implement any adjustments to its scallop management program that the State deems necessary to address anticipated changes in fishing effort in State waters. Adjustment of management measures could include reductions to State GHLs or closure of State waters. All vessels fishing for scallops under the jurisdiction of the State are required to carry an observer at all times. Effort and catch data will be collected by the State so that established guideline harvest amounts or crab bycatch limits are not exceeded. Given the State's management program currently in place for the scallop fishery and the State's ability to adequately monitor inseason catch amounts, closure of Federal waters to fishing for scallops should not pose a threat to the management of the scallop fishery in State waters.

Table 2. Alaska State scallop registration areas from where scallops were harvested in 1994-95[1], upper limit of GHRs (lbs shucked meat), 1995 Tanner (Tan) and king crab bycatch limits (number of crab), 1994 and 1995 scallop and crab catch amounts (in parenthesis) and season opening and closure dates (Ken Griffin, ADF&G, personal communication).

Area	GHR (catch)	Crab bycatch (catch)	1995 season open - closed dates
Yakutat	285,000	no crab limit	1/10/95 - 2/14/95
1995 catch	(245,000)[2]		
1994 catch	(259,206)		
Prince William Sound	50,000	Tan - 630	1/10/95- 1/26/95
1995 catch	(48,000)[2]	(69)[2]	
No 1994 fishery			
Cook Inlet	20,000	King - 138	8/15/95 -
1994 catch	(20,431)	(42)	
		Tan - 18,070	
		(13,300)	
Kodiak	400,000	King - 283	7/1/95 -
1994 catch	(381,850)	(157)	
		Tan - 199,500	
		(69,274)	
Dutch Harbor	170,000	King - 45	7/1/95 -
1994 catch	(1,931)	(6)	
		Tan - 50,500	
		(792)	
Alaska Peninsula	Permit	King - 85	7/1/95 -
1994 catch	(66,412)	(0)	
		Tan - 52,530	
		(26,379)	
Bering Sea	Permit	King - 17,000	7/1/95 -
1994 catch	(505,439)	(55)	
		Tan - 260,000	
		(262,500)	

1/ The Southeastern registration area is closed to fishing and no harvests were reported from the Adak registration area.
2/ Scallop catch and crab bycatch amounts do not include unreported amounts taken by the catcher/processor vessel fishing in the management area outside of State jurisdiction.

2.0 MANAGEMENT PROGRAM FOR THE ALASKAN SCALLOP FISHERY

2.1 Management Objective

The objective of the FMP is to prevent localized overfishing of scallop stocks and protect the long term productivity of the resource to allow for the achievement of optimum yield on a continuing basis. This objective is based on the premise that uncontrolled fishing for scallops in Federal waters could result in irreversible damage to the resource's ability to recover in a reasonable period of time. Fishing on a stock at a level that severely compromises that stock's future productivity is counter to the goals of the Magnuson Act and seriously jeopardizes the opportunity to harvest optimum yield on a continuing basis under a future management regime that would authorize a regulated fishery for scallops in Federal waters. Conservative management of the scallop resource is warranted given (1) unprecedented activity of vessels fishing for scallops in Federal waters outside the jurisdiction of Alaska State regulations, (2) the harvesting and processing capacity of the scallop fleet, which, if allowed to fish unregulated in Federal waters, could exceed State harvest guidelines by several orders of magnitude, (3) inadequate data on stock status and biology, and (4) the vulnerability of the scallop resource to localized depletion.

The management program authorized under this FMP conforms to the Magnuson Act's national standards as listed in Appendix B. Under this FMP, the prevention of overfishing of the Alaska scallop stocks and the maintenance of adequate reproductive potential for the scallop resource takes precedence over other economic, social, management and research considerations.

2.2 Optimum Yield and Overfishing

A fishery management plan for scallops must specify an optimum yield (OY) for the scallop fishery. The OY for a fishery means the amount of fish which will provide the greatest overall benefit to the nation, with particular reference to food production and recreational activities. The OY is specified on the basis of the maximum sustainable yield from the fishery, as modified by any relevant economic, social, or ecological factors. The advisory guidelines established under 50 CFR part 602 for the national standards for fishery conservation and management state the most important limitation on the specification of OY is that the choice of OY, and the conservation and management measures proposed to achieve it, must prevent overfishing (§602.11(b)).

The determination of OY requires a specification of maximum sustainable yield (MSY). Biomass estimates for scallops are lacking, and the continuing exploratory nature of this fishery into new areas makes numerical estimation of MSY for weathervane and other scallop species not possible at this time. NOAA recognizes that there are cases where the specification of MSY may either be impossible or irrelevant. This may be due to lack of assessment data ... or because biological resiliency or high fecundity of some stocks or other fishery characteristic may allow OY to become a descriptive statement only, making a numerical calculation of MSY unnecessary. Nonetheless, the OY should still be based on the best scientific information available (§ 602.10(f)(4)(v)).

Overfishing is a level of fishing mortality that jeopardizes the long-term capacity of a stock or stock complex to produce MSY on a continuing basis. The definition of overfishing for a stock or stock complex may be expressed in terms of maximum level of fishing mortality or other measurable standard designed to ensure the maintenance of the stock's productive capacity. Overfishing must be defined in a way to enable the Council and the Secretary to monitor and evaluate the condition of the stock or stock complex relative to the definition. Overfishing definitions must be based on the best scientific information available and reflect appropriate consideration of risk. Risk assessments should take into account uncertainties in estimating harvest levels, stock conditions, or the effects of environmental factors.

2.2.1 Assessment of the available scientific data

The State of Alaska's draft fishery management plan for scallops (Kruse, 1994) presents a succinct summary of the best scientific data available on Alaska scallop life history traits and other biological parameters that should be considered in assessing an appropriate concept of MSY, OY, and overfishing for the scallop fishery. Pertinent portions of the State's management plan addressing current management concerns about recruitment overfishing and sustainable yield are incorporated in this FMP and are repeated below as follows:

Recruitment Overfishing

Definition. It is widely accepted that fishery harvest levels should be prescribed in ways to prevent "recruitment overfishing"--the condition that occurs when stocks are reduced to levels too low to produce adequate numbers of young scallops--the future recruits to the fishery (Gulland 1983). Recruitment is a prerequisite for maintenance of a viable population, and is needed for sustainable harvests that support long-term economic benefits from the fishery.

Worldwide History of Scallop Overfishing. Although there are a number of cases of scallop fisheries that have been sustainable over long time periods....overfishing has occurred in many, if not most, scallop fisheries worldwide...Stock recovery has been either slow or non-existent. Attempts to develop aquaculture in many countries ... are largely attributable to the collapse of natural populations [Kruse (1994) provides examples of numerous cases of scallop overfishing that are not repeated here].....

Implications of Stock Structure. Prevention of overfishing requires knowledge about a species stock structure and the biological productivity of each stock. For species with populations that are well-connected by extensive larval drift, risk of overfishing is relatively low at least on an area-specific level. In such cases, local depletions can be replenished by settlement of larvae carried by ocean currents from spawning stocks located elsewhere. However, as described in section [1.3.4], a growing body of evidence indicates that many benthic invertebrates, such as scallops, exist as a number of discrete, self-sustaining populations. To prevent overfishing for species with such a population structure, it is necessary to manage each stock separately (Caddy 1989; Fevolden 1989; Sinclair et al. 1985.)

Unfortunately, the stock structure of weathervane scallops in Alaska is not well understood. Studies of genetic structure and comparative population characteristics (e.g., growth rate, gonadal somatic index) are needed to resolve uncertainties. In the absence of such information, a reasonable and conservative approach is to assume that each major fishing area compromises a separate stock (Caddy 1989; Sinclair et al. 1985). However, even with this approach, the possibility exists that multiple self-sustaining populations exist within a fishing area. For example, the apparent existence of separate self-sustaining populations of sea scallops on the Northern Edge and Northeast Peak of Georges Bank (Tremblay and Sinclair 1992; McGarvey et al. 1993) is somewhat unexpected given ocean currents and proximity of these areas to other scallop fishing grounds on Georges Bank.

Importance of Spawning Stock Biomass. Even after scallop stocks have been defined, overfishing will occur unless fishing mortality is limited to a level commensurate with the productivity of each stock based on life history and other biological characteristics. Worldwide, scallop populations are characterized by recruitment variability....Often, scallop populations are dominated by a few strong year classes that are separated by long periods of poor recruitment... Potential stock-recruitment relationships have not been well studied for scallops. A recent study by McGarvey et al. (1993)

provides a rare example with good evidence of a relationship between spawning stock (total egg production) and recruitment for sea scallops on Georges Bank. In that instance, higher egg production was directly related to higher recruitment.

[Conversely], it is commonly assumed that scallop recruitment is linked to environmental conditions (Hanock 1973)... However, even when recruitment of a marine species is primarily driven by environmental effects, it is commonly held that parental spawning biomass affects recruitment, at least at low population sizes...Recently, Peterson and Summerson (1992) showed that the bay scallop (Argopecten irradians concentricus) was recruitment limited due to reduced abundance of adults caused by a red tide (Ptychodiscus brevis) outbreak. In relating their findings to fishery management, the authors noted that a common assumption of shellfish fisheries management was that fishing pressure on adults will not adversely affect subsequent recruitment. Peterson and Summerson (1992) concluded that this assumption was unjustified.

Sustainable Yield

Ideally, an appropriate harvest rate is developed from yield models based on a species' life history traits and other biological parameters. Then, annual catches are specified by applying these harvest rates to annual biomass estimates derived from stock assessment surveys. Unfortunately, limited information on biological productivity is available for weathervane scallops to promote the conservation of stocks and sustained yields of the fishery. Biomass estimates are unavailable and yield models have not been developed.

In Alaska, most available information was collected during the early years of the fishery (Haynes and Powell 1968; Hennick 1970b, 1973), although it has been summarized more recently by Kaiser (1986). In the early 1950's the Bureau of Commercial Fisheries began systematic surveys to determine whether commercial quantities were available. The only assessment survey since 1972 was conducted in 1984 in lower Cook Inlet (Hammarstrom and Merritt 1985). Likewise, until the implementation of [the State's] onboard observer program in 1993, there have been no routine biological or fishery sampling programs conducted on weathervane scallops in Alaska.

Implications of Natural Mortality Rate. Natural mortality is one of the biological reference points commonly used in fisheries management to establish appropriate exploitation rates (Clark 1991). As discussed in section [1.3.3], the longevity (28 years) of weathervane scallops in Alaska implies that this species experiences a very low natural mortality rate (M approximates 0.16 or 15 percent annual mortality). The biological reference point, obtained by setting instantaneous fishing mortality (F) equal to M, implies that scallop harvest rates should not exceed 15 percent annually on any given stock. Unfortunately, other potentially useful benchmarks that would bear on the choice of appropriate exploitation rates for weathervane scallops are not presently available. A study of alternatives in is progress [by the ADF&G].

The biological reference point, F=M=0.16, implies that weathervane scallop stocks are at greater risk [illegible] for which an M=0.3 has been estimated (NPFMC 1990). Also, unlike many crab stocks [off Alaska], there are not stock assessments of weathervane scallop biomass. Given these two observations, maintenance of healthy weathervane scallop stocks poses a serious challenge to fishery managers.

Implications of Recruitment Variability. Large annual fluctuations in recruitment, typical of scallop populations, have management implications. Weathervane scallops spawn annually after reaching

maturity at age 3 or 4. This feature of multiple spawning (termed *iteroparity*) is likely to be an evolutionary response to environmentally-induced recruitment variations (Murphy 1968). Iteroparous species, with highly variable recruitment, are particularly vulnerable to overfishing when high levels of harvest create a recruit-only fishery.

Murphy (1967) simulated the effects of fishing on Pacific sardine (Sarinops sagax) age structure so that the population approached a single reproducing age class. Compared to an unfished populations with a protracted age structure, abundance of the fished population was much lower and more variable. The fished population recovered slowly even when fishing was terminated and it had a higher probability of extinction than the unfished population.

These results led Murphy (1967) to assert the need to maintain age structure in populations with long life spans that experience environmentally-driven recruitment. This same advice was advanced by Leaman (1991) for the long-lived rockfishes (Sebastes). By comparison of longevity with other scallop species (Orensanz et al. 1991), weathervane scallops, with a maximum age of 28 (Hennick 1973), may be the longest-lived scallop species in the world. That is, the advice of Murphy (1967, 1968) and Leaman (1991) is apropos.

Sustainability of Weathervane Scallop Harvests. Changes in the Alaskan scallop fishery through 1992 raised concerns that recent (through 1992) harvests may not be sustainable on a local or regional level for several reasons. First, recent landings were 2-3 times higher than the long-term average harvest taken over a 20-year period during the 1970s and 1980s. In fact, these harvests are at levels comparable to those taken in the late 1960s and early 1970s which proved not to be sustainable by the fishery. Reduced scallop abundance was at least partly responsible for the fishery collapse in the 1970s. Second, high harvests since 1990 were at least partly attributable to shifts in fishing effort to new scallop beds. Third, during 1992 limited inseason catch reports from some areas indicated that small scallops were constituting an increased portion of landings as had occurred prior to the fishery decline in the mid-1970s. Last, misreporting was suspected. If misreporting was widespread, it would seriously compromise the data base of historical catches upon which assessments of sustainable harvests are based.

2.2.2 Specification of OY and overfishing

Instead of specifying OY as a fishing rate or constant catch level, the long-term OY specification for the scallop resource in Federal waters off Alaska (all species) is specified as a numerical range. In the absence of biomass estimates needed to implement an exploitation rate harvest strategy, the OY is specified as the long-term productivity. The OY range proposed is zero to 1,100,000 pounds of shucked scallop meats, and is derived from historical catches harvested from Federal waters. The low end of the range is the lowest catch on record (zero pounds in 1978). The high end of the OY approximates the highest catch taken from Federal waters since the 'fishing up' period (1,087,450 pounds in 1993). During the period of time Federal waters are closed to fishing for scallops under section 2.3.1 of this FMP, OY is equal to zero for the same reasons that support the closure.

As discussed above in section 2.2.1, the lack of biological information on Alaskan scallops inhibits the numerical specification of overfishing. Although it is difficult to define precisely the level at which overfishing jeopardizes recovery of a stock, there are indicators of existing or impending overfishing that should be heeded. For the reasons discussed above, recent harvest levels of scallops off Alaska may not be sustainable. This concern, as well as other uncertainties about the scallop biomass and stock dynamics must be taken into account in developing an overfishing definition. Although overfishing could be defined as a fishing mortality rate for weathervane scallops, based on existing life history data, the lack of stock assessment information (surveys, population age or size structure) limit the use of an overfishing rate at this

time. As in the case for other stocks where very little biological information is available (Rosenberg et al. 1993), overfishing can be defined as landings that exceed optimum yield. As data collected from the fisheries and/or assessment surveys of the scallop resource are analyzed, overfishing for scallops may be defined on a fishing mortality rate basis. Until better information becomes available, overfishing is defined as landings that exceed optimum yield.

The scallop FMP must ensure that fishing effort on the scallop stocks will not cause OY (and the overfishing level) to be exceeded. An interim closure of Federal waters to fishing for scallops during the period of time management agencies examine existing or new fishery data is necessary to assess the merits of different conservation measures needed to control a fishery in Federal waters. The long-lived nature of scallops means that most scallops not harvested in Federal waters during the closure would become available when either the FMP closure expires or the FMP is superseded by either an alternative management plan or FMP amendment that authorizes a fishery in Federal waters in a manner that does not jeopardize the long-term capacity of the stocks to produce MSY.

Because scallops have only been harvested by U.S. vessels in the past, and effort remains high, it is likely that the OY can be fully harvested by U.S. vessels, and fully processed by U.S. processors in future years. In fact, current capacity of the U.S. scallop fleet in Alaska exceeds current guideline harvest levels for scallops. Hence, no considerations have been made to allow a foreign fishery on Alaskan scallops.

2.3 Management Measures

2.3.1 Closure of Federal waters

The only management measure authorized under the proposed FMP to control fishing effort and avoid overfishing of scallop stocks is an interim closure of Federal waters off Alaska to fishing for scallops to protect the scallop resource from unregulated fishing and localized overfishing during the period of time a more long-term fishery management plan is prepared that would allow for controlled harvesting of scallops in Federal waters. Closure of Federal waters is necessary and appropriate for the protection and promotion of the long-term health of the scallop resource and stability of the scallop fishery under a future fishery management plan authorizing fishing for scallops in Federal waters. Closure of Federal waters to prevent an unregulated fishery also would mitigate any potentially adverse impact crab bycatch in the scallop fishery may have on either crab stocks or their habitat off Alaska. Given that the interim closure is intended to be superseded by a long-term FMP, the closure would be effective until either (1) a date 1 year from the date the regulations implementing the FMP become effective, or (2) the FMP is superseded by a future FMP or FMP amendment that implements management measures that would allow the controlled harvest of scallops in Federal waters without overfishing.

2.3.2 Data assessment and collection

NMFS, in coordination with other management agencies, should initiate efforts to identify and gather the data needed to improve management agency understanding of the dynamics of the scallop resource and the effect of exploitation on the stocks capacity to produce MSY on a continuing basis. The type of information that should be pursued Alaska include (1) stock abundance and size/age structure, (2) scallop biology, life history, and stock production parameters, (3) analyses of population thresholds and recruitment overfishing; (4) estimation of optimum dredge ring size or minimum shell height based on studies of rates of growth and mortality; (5) investigations of exploitation rates and alternative management strategies; (6) genetic stock structure; and (7) new gear designs to reduce bycatch and to minimize adverse effects on bottom habitat. This objective may be attained, in part, with data collected by the Alaska State observer program. However, assessments of the scallop resource off Alaska, as well as the conduct of other scallop research will be dependent on Federal funding, State of Alaska general fund appropriations, or future amendments to the

FMP that would authorize experimental fishing under Federal permit conditions.

2.3.3 Administrative and enforcement costs

Administration and enforcement of the FMP would involve minimal costs given the limited nature of the management measure authorized under the FMP, i.e., closure of Federal waters to fishing for scallops. Administrative costs will increased as staff resources are required to develop future management measures. Significant costs would result from a meaningful data collection program that, ideally would include a resource assessment of the Alaska scallop stocks. A good comprehensive survey of the sea scallop grounds in the Gulf of Alaska and the Bering sea would require a 90-day cruise. Such a cruise probably cannot be part of ongoing groundfish research cruises because a different type of sampling gear, such as a specialized scallop dredge, likely would be required. The estimated cost of such a survey would be about $540,000 (assume a vessel charter with scientific personnel cost at $6,000 per day for a 90-day cruise). There would also be a need for data entry, data workup, and general staffing functions to make the information useable, estimated to be one staff -year.

A desirable part of the data collection program would involve collection of fisheries statistics and biological specimens from the fisheries for status of stocks analyses. A closure of Federal waters to fishing for scallops would constrain this data to State waters until such time the FMP is amended or superseded to authorize a fishery in Federal waters.

2.3.4 Impact on the fishery

No foreign vessels have ever participated in the Alaska scallop fishery and no Indian treaty fishing right exist for scallops. Therefore, the impact of the interim closure of Federal waters to fishing for scallops authorized under this FMP would be incurred solely by the domestic commercial fishery.

Closure of the EEZ to fishing for scallops would cause substantial impact to participants in the Alaskan scallop fisheries. Of the 16 vessels making landings of scallops in 1994, 11 vessels landed no other catch, indicating their dependence on this resource. These vessels accounted for 88 percent of the scallops harvested in Federal and State waters during 1994, or approximately 1.1 million lbs of shucked scallop meats. Using the 1994 average exvessel price of $6.00/lb and assuming that 14 percent of the total annual scallop landings would continue to come from State waters, this would equate to an annual forgone revenue of about $ 5.7 million. During 1994, an additional 5 vessels landed 0.1 million lbs of shucked scallop meats, equating to the potential for another $0.52 million in foregone revenue under the proposed closure. The scallop catch by these 5 vessels ranged from less than 1 percent to 46 percent of these vessels' total 1994 landed catch of all species, including groundfish and crab. Taken together, a one year closure of Federal waters the EEZ could result in foregone revenue on the order of $6.12 million.

Options available to vessels which would not be able to fish for scallops in the EEZ are limited. Beyond existing fisheries under Council management, the opportunities and capabilities of this fleet to engage in other fisheries imply a shift to one of several alternatives: (1) State-managed fisheries within Alaska; (2) state or federally managed fisheries in the U.S. outside Alaska; or (3) high-seas or foreign fisheries elsewhere in the world. Some of the vessels previously harvested scallops in the Atlantic Ocean, and may still qualify to fish for scallops on the East Coast. Although many scallop vessels could be rigged to fish for groundfish, the opportunities for new vessels to participate in North Pacific fisheries are limited. The Council recently adopted a moratorium on new vessels entering the groundfish and crab fisheries in the North Pacific.

Opportunities for new entrants in Alaska state-managed fisheries are restricted by the state's limited entry program that covers most of the important commercial fisheries, including salmon, sablefish, herring, and crab. In order to access most of these fisheries, new entrants from EEZ fisheries would have to purchase a

permit, as well as adopt necessary vessel and gear modifications. In the case of salmon, asking prices for permits vary from around $50,000 up to over $250,000 for the most desirable areas. Salmon vessels in some areas have been developed to operate in specific regulatory and oceanographic conditions, such that halibut or groundfish boats may prove inadequate without modifications. The Alaska state fisheries are managed under a limited entry permit system because of existing concerns over excess capacity, such that the entry of vessels from Council-managed fisheries would require the exit of an existing vessel. In general, there appear to be few, if any, unexploited opportunities in existing state-managed fisheries that are capable of absorbing an influx of new entrants from the EEZ fisheries.

Outside domestic waters, fishing opportunities are less certain, although it is recognized that excess harvesting capacity exists for many of the world's developed fisheries. Following the extension of fisheries jurisdiction in the mid-1970s, most coastal nations--led by the U.S.--endeavored to claim the economic benefits associated with the marine resources in their exclusive economic zones, greatly reducing the opportunities for distant water fleets of some countries. As a result, access to the coastal waters of foreign nations must be arranged through joint venture arrangements, in competition with the distant water fleets of many other nations, such as Japan and Korea. However, the shift to foreign fisheries requires both logistical and diplomatic arrangements that may be beyond the scope of many small boat operators. Also, opportunities for the Alaska fleet in foreign fisheries likely favor technologically advanced, higher valued vessels not readily available in the host country.

In summary, the problems associated with excess capacity and overcapitalization cannot be easily overcome by shifting unneeded vessels to other fisheries. This is not so much because of an incompatibility of technology, as the dilemma of widespread overcapitalization. Efficient, adaptable vessels are capable of shifting to other fisheries, and may well enter different fisheries in response to economic efficiency criteria. Entrepreneurs may also be capable of finding and competing in a variety of world-wide fisheries. Overall, however, there is no simple means of shifting excess Alaska EEZ vessels into other fisheries in the current environment, primarily because already there appears to be more than adequate capacity throughout the Alaskan, U.S. and world fishing industry.

There continues to be the possibility of a fishery for scallops in State waters. However, only about 14 percent of the resource was taken in State waters in 1994. Any State fishery would likely have to be of very short duration to prevent that portion of the State GHL from being exceeded.

Because of the longevity and low natural mortality associated with weathervane scallops, the yield from this fishery would essentially be recouped when the fishery is reopened, either one year after the proposed FMP goes into effect, or before that time if the FMP is superseded by FMP amendment instituting a comprehensive management plan for scallops.

3.0 APPENDICES

Appendix A - Description of the Alaska Scallop Fishery and Management

Interest in an Alaskan scallop fishery has existed since the early 1950's when the Bureau of Commercial Fisheries began systematic surveys to determine if commercial quantities were available. The first commercial deliveries of weathervane scallops were made in 1967. Since then, the numbers of vessels, numbers of landings and harvest (weight of shucked meats) have varied annually (Table A.1.1). Total commercial harvest of scallops has fluctuated from a high of 157 landings totaling 1,850,187 pounds of shucked meats by 19 vessels in 1969 to no landings in 1978. Prices and demand for scallops have remained high since fishery inception. Harvests in 1990 and 1991 were the highest on record since the early 1970's. The 1992 harvest was even higher at 1,810,788 pounds. On average, about two-thirds of the scallop harvest has been taken off Kodiak Island and about one-third has come from the Yakutat area; other areas have made minor contributions to overall landings. Harvest peaks have occurred as new beds were discovered or old beds recovered and then became depleted (Table A.1.2). From 1969 through 1990, landings from State waters averaged about 39 percent of the total but more recent landings increasingly have been taken mostly from Federal waters (Table A.1.3). Changes in catch-per-unit-effort (CPUE) could not be monitored, as the unit measure of effort (number of days as measured by trips) has not been consistent through the time series. Many vessels switched from landing fresh to frozen product during the late 1980's, extending the average trip from about 10 days to perhaps 20 or more.

The size of the scallop fishing fleet off Alaska has fluctuated since the fishery began in 1967. Since then, up to 19 vessels per year have participated in the fishery. In 1992, only 7 vessels were actively fishing for scallops. Annual variability in the number of participants is due to both scallop abundance and the potential revenues generated by other fisheries (Kaiser 1986; Bourne 1991). Historically, many of the vessels participating in the fishery have dropped out after only one year (Table A.1.4). By 1992, only one vessel had participated for more than four consecutive years. Examination of the number of landings made by vessels in 1994 indicates that 11 out of 16 participants were "full time" scallopers, whereas vessels may have fished part time for scallops in previous years (Table A.1.5). Since the beginning of the fishery, scallops have been harvested by vessels and companies from the East Coast (Browning 1980). The same situation occurred through 1994; of the 16 vessels used to fish for scallops in 1994, 7 were registered to persons living in Alaska, and 9 outside the State, primarily from the mid-Atlantic area. No foreign vessels have ever participated in the scallop fishery in Alaska, and no Indian treaty fishing rights exist for this fishery.

Throughout the history of the Alaska scallop fishery, vessels fished nearly exclusively for weathervane scallops. Although scallop fisheries could potentially target species other than weathervanes, they have not done so. Landings of other scallop species were made by one vessel in 1991 and 1992, but due to confidentiality of the data, total landings of other species cannot be reported. Landings of other scallops may have been made in earlier years, but scallop species were not differentiated on fish tickets prior to 1991. Apparently, some amount of pink scallops were landed in 1979 (Kaiser 1986). Little information on the abundance and distribution of these other species is available. It is not known to what extent the scallop species are harvested by recreational or subsistence fisheries, however based on anecdotal information, some recreational diving for pink scallops occurs in Southeast Alaska.

Currently, the "average" scallop vessel is about 90-110 ft long and carries a crew of 12. In the 1980's, several small (< 50 ft) vessels participated in the fishery. The length distribution of vessels participating in the scallop fishery since 1980 is shown in Table A.1.6. The gear used to catch scallops commercially is the dredge of a standard design, with a regulated minimum ring size (Figure A.1). This type of fishing gear typically harvests only 5-35 percent of the scallops in their path, depending on dredge design, target species, bottom type, and other factors (McLoughlin et al. 1991). Although dredge width has varied in size through the history of the fishery, recent State regulations have limited dredges to a maximum width of 15 feet.

Traditionally, scallops have been processed at sea by manual shucking, with only the meats (adductor muscles) landed. The technology for automated mechanical shucking exists, and apparently can process Alaskan scallops. However, this type of shucking was recently prohibited by the State for weathervane scallops and in the East Coast sea scallop fishery to control effort.

Fishing operations at sea generally involve the following steps: 1) dredge setting, 2) towing for about one hour, 3) dredge retrieval, 4) dumping of the catch on deck, 5) sorting out scallops to be retained, and 6) discarding of debris, small scallops and bycatch of other species. Retained scallops are shucked by the crew, and usually washed, sorted, and frozen (or iced) at sea. DuPaul and Carnegie (1994) reported on scallop fishing procedures during the weathervane scallop fishery off Yakatat in July 1993. They reported that fishermen generally retained most large scallops (> 85 mm SH). Small scallops (< 85 mm SH) comprised a very small percentage (< 5 percent) of the catch, and were not retained. Scallops in the 100-130 mm SH range comprised the vast majority of the catch, corresponding to meat counts of 28 to 48 meats per pound of shucked adductor muscles. In the 1993 scallop fisheries statewide, the largest scallops were taken in the Kodiak Island and Bering Sea areas (Figures A.2 and A.3).

Economic trends of the fishery depend upon the performance measures considered. For example, vessels averaged 212,000 pounds each during the early "fishing-up period" (1970-1973) of the fishery. During 1974-1986, landings per vessel averaged only about one-third (66,000 pounds) of the 1970-1973 average as stocks recovered from high harvest levels, but increased to about one-half (114,000 pounds) of the original level during the 1987-1991 period. Note that the average landings per vessel in 1992 (258,684 pounds) was the highest in the history of the fishery (Table A.1.1). On the other hand, average gross receipts (exvessel value) per vessel reveal a different trend due to price effects during these same three time periods: $234,000, $178,000, and $400,000, respectively.

Average annual exvessel price has increased through the time series, with a distinct break occurring between 1975 and 1980 (Table A.1.1). In the early years of the fishery, 1968-1975, exvessel price per pound ranged from $0.85 to $1.40. Prices in the early 1980's were much higher, with exvessel prices ranging from $3.77 to $4.88. Prices decreased somewhat through the early 1990s, with a range of $3.12 to $3.88 observed from 1985 to 1992. Price increased in 1993 and 1994 to $5.00 and $6.00, respectively (Ken Griffin, ADF&G, personal communication).

Table A.1.1. Historic number of vessels, number of landings, landed weight of shucked meats, price per pound, exvessel value, landings per vessel, and exvessel value per vessel for the weathervane scallop fishery in Alaska during 1967-1994. All data for 1967-1968, and prices and exvessel values for 1967-1975 and 1979 were taken from Kaiser (1986); all other data were summarized from fish tickets (Kruse 1994). The 1994 data are preliminary. In years when only one or two vessels participated in a fishery, the harvest statistics are confidential.

Year	No. of Vessels	No. of Landings	Landings Wt. (lbs)	Price ($/lb)	Landings Exvessel Value ($)	(lbs) per Vessel	Value ($) per Vessel
1967	<-----------------			Confidential		----------------->	
1968	19	125	1,677,268	0.85	1,425,678	88,277	75,036
1969	19	157	1,850,187	0.85	1,572,659	97,378	82,772
1970	7	137	1,440,338	1.00	1,440,338	205,763	205,763
1971	5	60	931,151	1.05	977,709	186,230	195,542
1972	5	65	1,167,034	1.15	1,342,089	233,407	268,418
1973	5	45	1,109,495	1.20	1,331,394	221,881	266,279
1974	<-----------------			Confidential		----------------->	
1975	4	56	435,672	1.40	609,941	108,918	152,485
1976	<-----------------			Confidential		----------------->	
1977	<-----------------			Confidential		----------------->	
1978	0	0	0	-	0	0	0
1979	<-----------------			Confidential		----------------->	
1980	8	56	632,535	4.32	2,732,551	79,06,7	341,569
1981	18	101	924,441	4.05	3,743,986	51,358	207,999
1982	13	120	913,996	3.77	3,445,765	70,307	265,059
1983	6	31	194,116	4.88	947,286	32,353	157,881
1984	10	61	389,817	4.47	1,742,482	38,982	174,248
1985	8	53	647,679	3.12	2,020,758	80,599	252,595
1986	9	86	682,622	3.66	2,498,397	75,847	277,600
1987	4	55	583,043	3.38	1,970,685	145,761	492,671
1988	4	47	341,070	3.49	1,190,334	85,268	297,584
1989	7	54	525,598	3.68	1,934,201	75,085	276,314
1990	9	144	1,488,64	3.37	5,016,724	165,405	557,414
1991	7	144	1,191,014	3.76	4,478,213	170,145	639,745
1992	7	137	1,810,788	3.88	7,028,702	258,684	1,004,100
1993	15	155	1,428,976	5.00	7,144,880	95,265	476,325
1994	16	118	1,235,267	6.00	7,411,614	77,204	463,226

Table A.1.2. Landings of scallops by year, registration area, and species, 1980-1994. Only landings from registration areas that contributed substantially to the total annual catch are listed separately. The "All Areas" catch listed for each year is the total catch from all areas off Alaska.

		Weathervane Scallops		Pink Scallops		Annual Totals	
		Pounds	Vessels	Pounds	Vessels	Pounds	Vessels
Year	Registration Area						
1980	(A) Southeastern Alaska	*	2	0	0	*	2
	(D) Yakutat	**	6	0	0	**	6
	(K) Kodiak	371,018	7	0	0	371,018	7
	All Areas	632,535	8	0	0	632,535	8
1981	(A) Southeastern Alaska	*	1	0	0	*	1
	(D) Yakutat	**	10	0	0	**	10
	(K) Kodiak	460,890	15	0	0	460,890	15
	All Areas	924,441	18	0	0	924,441	18
1982	(A) Southeastern Alaska	*	3	0	0	*	3
	(D) Yakutat	168,353	6	0	0	168,353	6
	(K) Kodiak	435,802	8	0	0	435,802	8
	(M) Alaska Peninsula	205,534	6	0	0	205,534	6
	(O) Dutch Harbor	**	5	0	0	**	5
	All Areas	913,996	13	0	0	913,996	13
1983	(A) Southeastern Alaska	*	1	0	0	*	1
	(K) Kodiak	**	4	0	0	**	4
	(M) Alaska Peninsula	*	1	0	0	*	1
	(H) Cook Inlet	*	1	0	0	*	1
	All Areas	194,116	6	0	0	194,116	6

Table A.1.2 (continued)

		Weathervane Scallops		Pink Scallops		Annual Totals	
		Pounds	Vessels	Pounds	Vessels	Pounds	Vessels
Year	Registration Area						
1984	(D) Yakutat	*	2	0	0	*	2
	(K) Kodiak	309,502	6	0	0	309,502	6
	(H) Cook Inlet	*	3	0	0	*	3
	All Areas	389,817	9	0	0	389,817	9
1985	(D) Yakutat	14,221	4	0	0	14,221	4
	(K) Kodiak	*	3	0	0	*	3
	(M) Alaska Peninsula	*	1	0	0	*	1
	(O) Dutch Harbor	*	3	0	0	*	3
	(H) Cook Inlet	*	1	0	0	*	1
	All Areas	647,679	8	0	0	647,679	8
1986	(D) Yakutat	*	2	0	0	*	2
	(K) Kodiak	180,600	5	0	0	180,600	5
	(O) Dutch Harbor	387,209	5	0	0	387,209	5
	(H) Cook Inlet	*	3	0	0	*	3
	(Q) Adak - Bristol Bay - Bering Sea	*	1	0	0	*	1
	All Areas	682,622	9	0	0	682,622	9

		Weathervane Scallops		Pink Scallops		Annual Totals	
		Pounds	Vessels	Pounds	Vessels	Pounds	Vessels
Year	Registration Area						
1987	(D) Yakutat	*	1	0	0	*	1
	(K) Kodiak	*	3	0	0	*	3
	(O) Dutch Harbor	*	2	0	0	*	2
	(H) Cook Inlet	*	1	0	0	*	1
	(Q) Adak - Bristol Bay - Berig Sea	*	2	0	0	*	2
	All Areas	583,043	4	0	0	583,043	4
1988	(D) Yakutat	*	1	0	0	*	1
	(K) Kodiak	*	3	0	0	*	3
	(M) Alaska	*	1	0	0	*	1
	(O) Dutch Harbor	*	1	0	0	*	1
	All Areas	341,070	4	0	0	341,070	4
1989	(D) Yakutat	*	1	0	0	*	1
	(K) Kodiak	**	5	0	0	**	5
	(O) Dutch Harbor	*	1	0	0	*	1
	All Areas	534,763	7	0	0	534,763	7

Year	Registration Area	Weathervane Scallops		Pink Scallops		Annual Totals	
		Pounds	Vessels	Pounds	Vessels	Pounds	Vessels
1990	(A) Southeastern Alaska	**	4	0	0	**	4
	(D) Yakutat	442,310	8	0	0	442,310	8
	(K) Kodiak	697,003	7	0	0	697,003	7
	(M) Alaska Peninsula	*	2	0	0	*	2
	(O) Dutch Harbor	*	1	0	0	*	1
	(Q) Adak - Bristol Bay - Bering Sea	*	1	0	0	*	1
	All Areas	1,488,642	9	0	0	1,488,642	9
1991	(A) Southeastern Alaska	*	3	0	0	*	3
	(D) Yakutat	402,571	5	0	0	402,571	5
	(K) Kodiak	514,348	4	0	0	514,348	4
	(M) Alaska Peninsula	*	1	0	0	*	1
	(O) Dutch Harbor	*	1	*	1	*	2
	(Q) Adak - Bristol Bay - Bering Sea	*	3	*	1	125,523	4
	All Areas	1,136,713	7	*	1	1,191,014	8
1992	(A) Southeastern Alaska	*	1	0	0	*	1
	(D) Yakutat	1,020,968	7	0	0	1,020,968	7
	(K) Kodiak	*	3	0	0	*	3
	(O) Dutch Harbor	*	1	*	1	*	1
	(E) Prince William Sound	208,836	4	0	0	208,836	4
	All Areas	1,741,578	7	*	1	1,810,788	7

		Weathervane Scallops		Pink Scallops		Annual Totals	
		Pounds	Vessels	Pounds	Vessels	Pounds	Vessels
Year	**Registration Area**						
1993	(Q) Bering Sea	531,668	9	0	0	531,668	9
	(D) Yakutat	256,493	10	0	0	256,493	10
	(K) Kodiak	374,908	10	0	0	374,908	10
	All Areas	1,428,976	15	0	0	1,428,976	15
1994	(Q) Bering Sea	505,439	9	0	0	505,439	9
	(D) Yakutat	259,206	12	0	0	259,206	12
	(K) Kodiak	381,850	10	0	0	381,850	10
	All Areas	1,235,269	17	0	0	1,235,269	17

* Confidential data

** Data masked to prevent extraction of confidential data

Table A.1.3. Percentage of Alaska scallop landings from State (within 3 miles) and Federal waters (3-200 miles), by year from 1990 through 1994.

Year	State Waters	Federal waters
1990	46.9%	53.1%
1991	37.9%	62.1%
1992	73.6%	26.4%
1993	23.9%	76.1%
1994	13.7%	86.3%

Table A.1.4 Number of vessels participating in the scallop fishery 1980-1992, the number of years participating.

Number of Years Participating

Year	1	2	3	4	5	6	7	8	9	10	11	12	13
1980	8	0	0	0	0	0	0	0	0	0	0	0	0
1981	13	5	0	0	0	0	0	0	0	0	0	0	0
1982	4	6	3	0	0	0	0	0	0	0	0	0	0
1983	4	0	1	1	0	0	0	0	0	0	0	0	0
1984	4	2	1	1	1	0	0	0	0	0	0	0	0
1985	6	0	1	0	1	1	0	0	0	0	0	0	0
1986	5	2	0	0	0	1	1	0	0	0	0	0	0
1987	0	2	0	1	0	0	0	1	0	0	0	0	0
1988	1	0	2	0	0	0	0	0	1	0	0	0	0
1989	3	2	0	1	0	0	0	0	0	1	0	0	0
1990	2	3	2	0	1	0	0	0	0	0	1	0	0
1991	3	0	2	1	0	1	0	0	0	0	0	1	0
1992	1	2	0	2	1	0	0	0	0	0	0	0	1

Note: No vessels fished in 1978, and only two fished in 1979; of these, one fished for only 1 year, and one fished through 1982.

Table A.1.5 Number of vessels participating in the scallop fishery 1980-1992, by landing category.

Number of Landings Per Vessel

Year	1-5	6-10	11-15	16-20	21-25	26-30
1980	4	2	1	0	1	0
1981	12	3	2	1	0	0
1982	5	2	5	0	1	0
1983	5	0	0	0	1	0
1984	6	1	0	0	2	0
1985	7	0	0	2	0	0
1986	3	3	1	2	0	0
1987	1	2	0	0	0	1
1988	2	0	1	0	1	0
1989	3	3	0	1	0	0
1990	1	3	2	1	1	1
1991	1	1	3	1	2	0
1992		1	2	3	1	0

Table A.1.6 Number of vessels participating in the scallop fishery 1980-1992, by vessel length category.

Length Category (ft)

Year	<50	50-70	71-90	91-110	111-130	131-150	>150
1980	0	1	5	2	0	0	0
1981	0	2	11	4	0	1	0
1982	2	0	8	3	0	0	0
1983	4	0	1	1	0	0	0
1984	4	2	1	2	0	0	0
1985	3	1	1	3	0	0	0
1986	3	0	1	3	1	1	0
1987	1	0	0	2	0	1	0
1988	0	0	1	2	0	1	0
1989	0	1	2	3	1	0	0
1990	0	1	2	5	1	0	0
1991	0	1	1	1	2	1	1
1992	0	1	2	1	1	1	1
1993	0	3	8	2	1	1	0
1994	0	4	8	2	1	1	0

Note:Prior to 1980, nearly all vessels were 70-90 ft. **One missing vessel in 1987.**

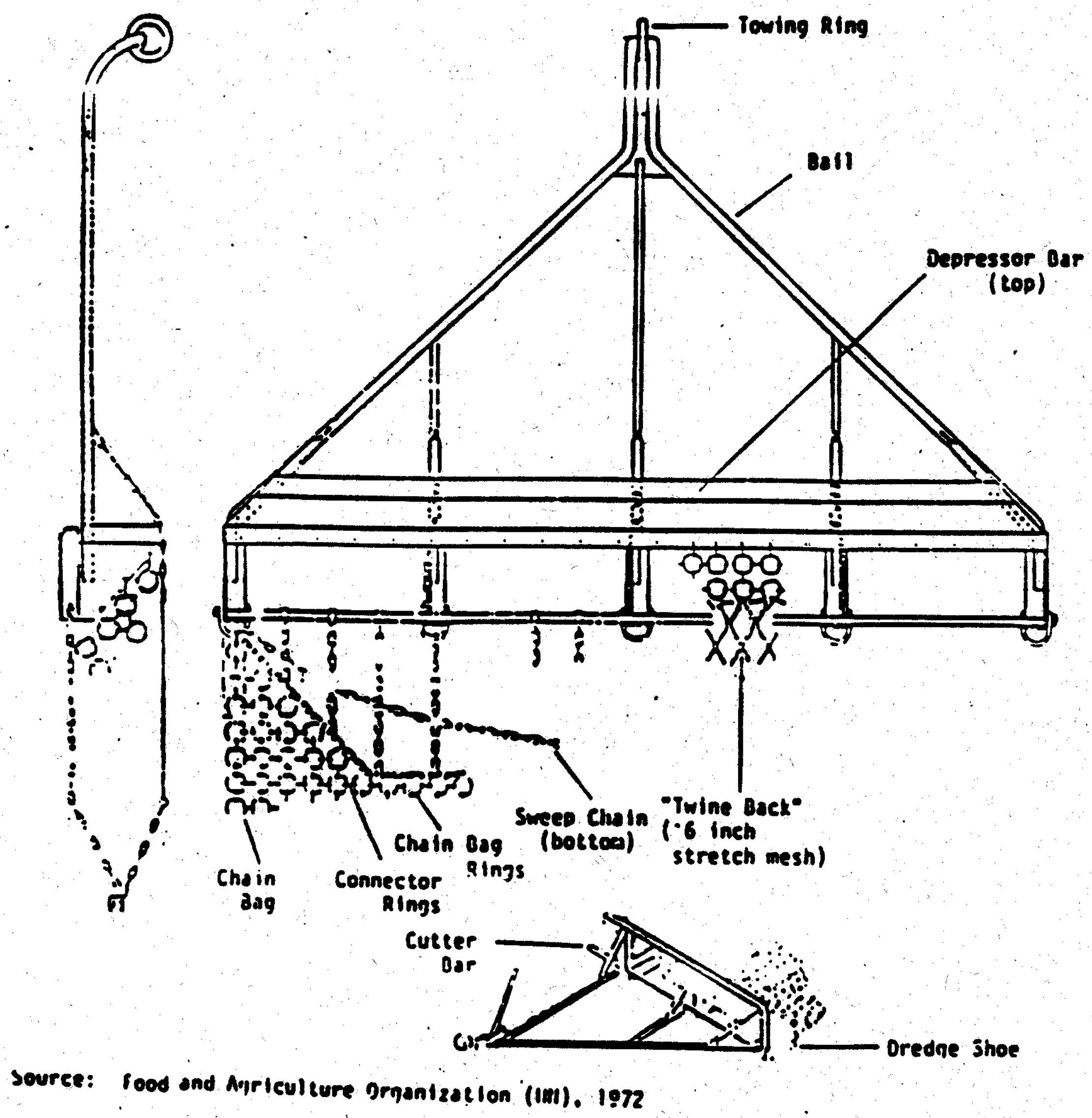

Figure A.1 Scallop dredge design used in the U.S. east coast and Alaska sea scallop fisheries.

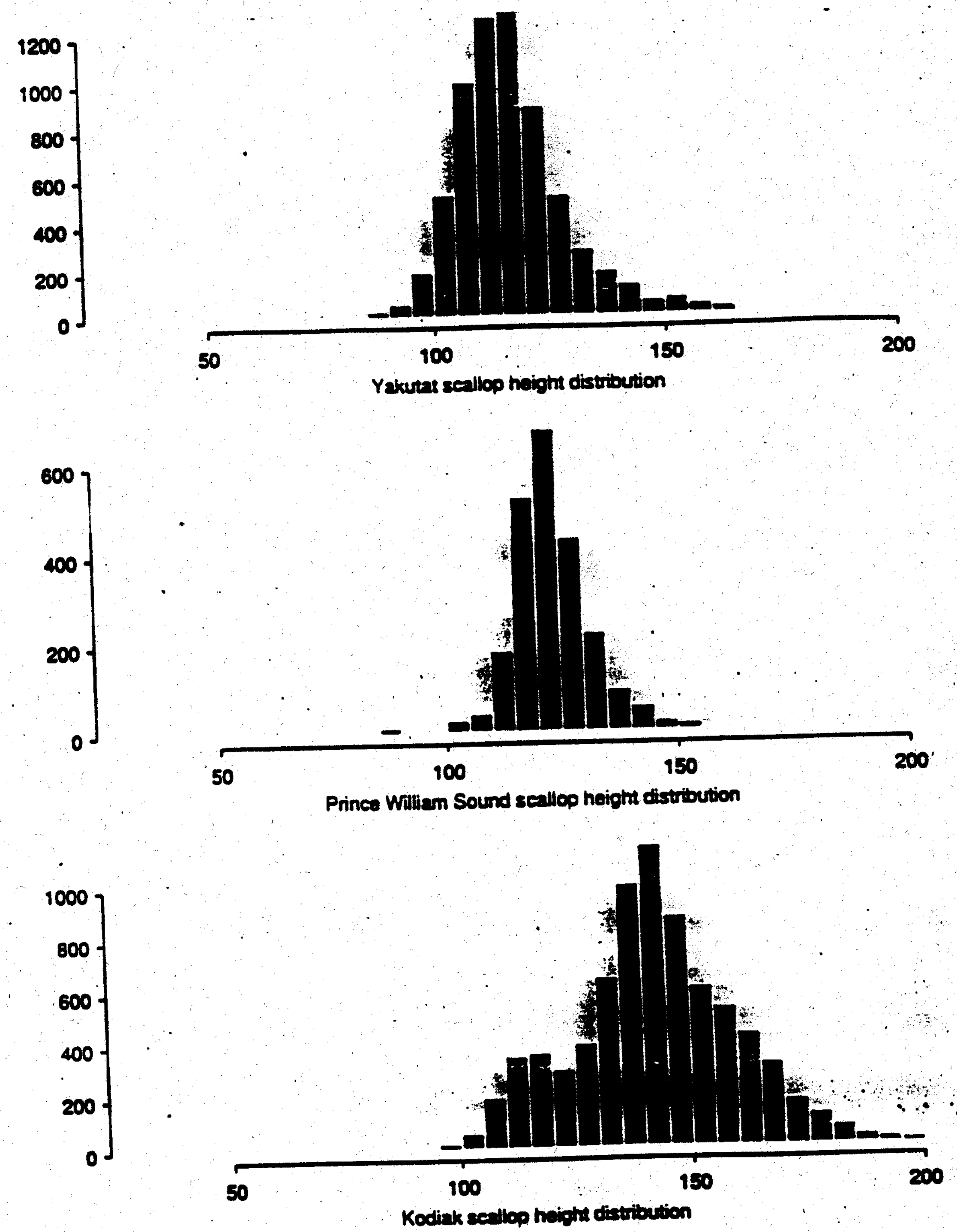

Figure A.2 Size frequency of scallops caught in the Yakutat, Prince William Sound, and Kodiak Management Areas during the 1993 scallop fishery. From Urban et al. (1994).

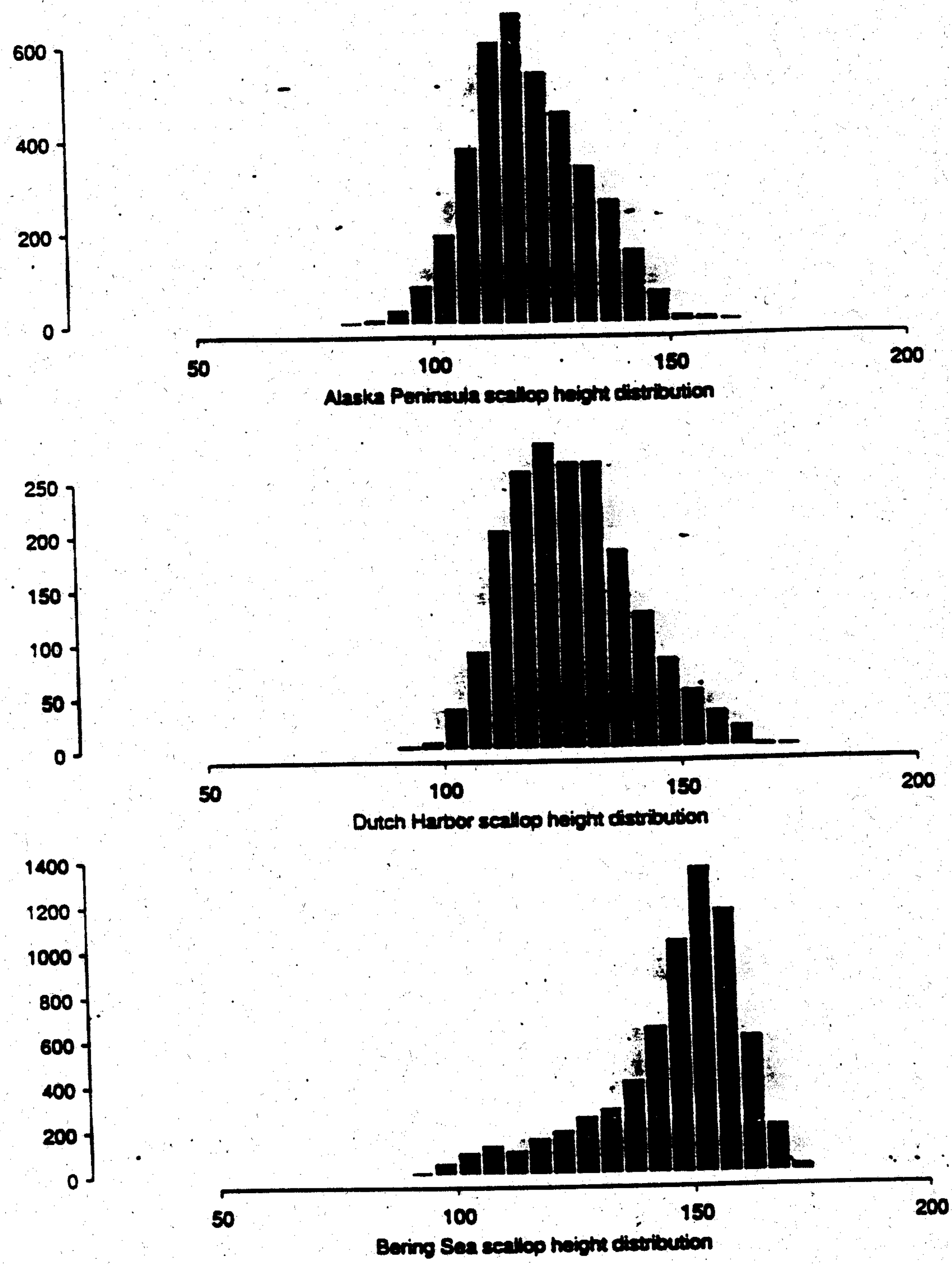

Figure A.3 Size frequency of scallops caught in the Alaska Peninsula, Dutch Harbor, and Bering Sea Management Areas during the 1993 scallop fishery. From Urban et al. (1994).

Appendix B - National Standards of the Magnuson Fishery Conservation and Management Act

The Magnuson Act (Section 301) sets the national standards for fishery conservation and management. Any fishery management plan prepared, and any regulation promulgated to implement any such plan, pursuant to this title shall be consistent with the following national standards for fishery conservation and management:

(1) Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry.

(2) Conservation and management measures shall be based upon the best scientific information available.

(3) To extend the practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination.

(4) Conservation and management measures shall not discriminate between residents of different States. If it becomes necessary to allocate or assign fishing privileges among various United States fishermen, such allocation shall be (A) fair and equitable to all such fishermen; (B) reasonably calculated to promote conservation; and (C) carried out in such manner that no particular individual, corporation, or other entity acquires an excessive share of such privileges.

(5) Conservation and management measures shall, where practicable, promote efficiency in the utilization of fishery resources; except that no such measure shall have economic allocation as its sole purpose.

(6) Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fishery resources, and catches.

(7) Conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication.

4.0 REFERENCES

Adams, A.E. 1979. Life history of the snow crab Chionoecetes opilio, a literature review. University of Alaska, Sea Grant Report 78-13, 141 p.

Bourne, N. 1986. Bivalve fisheries: their exploitation and management with particular reference to the Northeast Pacific region. Pages 2-13 *in* G.S. Jamieson and N. Bourne, (eds.) North Pacific workshop on stock assessment and management of invertebrates. Canadian Special Publication of Fisheries and Aquatic Sciences 92.

Bourne, N. 1991. Fisheries and Aquaculture: West Coast of North America. In: S.E. Shumway, (ed.), Scallops: biology, ecology, and aquaculture. Elsevier, N.Y. 1991.

Bourne, N. and R.M. Harbo. 1987. Size limits for pink and spiny scallops. In: Harbo, R.M. and G.S. Jamieson (eds.) 1987. Status of invertebrate fisheries off the Pacific coast of Canada (1985/86). Can. Tech. Rep. Fish. Aquat. Sci. 1576:113-122.

Browning, R. R. 1980. Fisheries of the North Pacific. Alaska Northwest Publishing Co, Anchorage, 423p.

Caddy, J.F. 1989. A perspective on the population dynamics and assessment of scallop fisheries, with special reference to the sea scallop, *Placopecten magellanicus* Gmelin. Pages 559-589 in J.F. Caddy, editor. Marine invertebrate fisheries: their assessment and management. John Wiley and Sons, New York.

Cimberg, R., T. Gerrodette, and K. Muzik. 1981. Habitat Requirements and Expected Distribution of Alaska Coral.

Clark, W.G. 1991. Groundfish exploitation rates based on life history parameters. Canadian Journal of Fisheries and Aquatic Sciences 48: 734-750.

Crag, S.M., and D.J. Crisp. 1991. The biology of scallop larvae. Pages 75-132 in S.E. Shumway, editor. Scallops: biology, ecology and aquaculture. Developments in Aquaculture and Fisheries Science 21, Elsevier, New York.

DuPaul, W.D. and R.B. Carnegie. 1994. Observations of the Alaskan sea scallop *(Patinopecten caurinus)* fishery Yakatat, Alaska 1993. Virginia Institute of Marine Science Report No. 94-3.

Fevolden, S.E. 1989. Genetic differentation of the Iceland scallop Chlamys islandica (Pectinidae) in the northern Atlantic Ocean. Marine Ecology Progress Series 51:77-75.

Foster, N.R. 1991. Intertidal bivalves: a guide to the common marine bivalves of Alaska. University of Alaska Press, Fairbanks.

Gould, E., Greig, R.A., Rusanowsky, D., and B.C. Marks. 1985. Metal-exposed sea scallops, Placopecten magellanicus: A comparison of the effects and uptake of cadmium and copper. In F.J. Vernberg, F.P. Thurberg, A. Calabrese, and W.B. Vernberg (Eds), Marine Pollution and Physiology: Recent Advances. Univ. South Carolina Press, Columbia S.C. pp. 157-186.

Gould, E., and B.A. Fowler. 1991. Scallops and Pollution. In: Sandra E. Shumway, (Ed), Scallops: biology, ecology, and aquaculture. Elsevier, N.Y. 1991.

Gulland, J.A. 1983. Fish stock assessment: a manual of basic methods. John Wiley and Sons, New York.

Hammarstom, L.F., and M.F. Merritt. 1985. A survey of Pacific weathervane scallops *(Pecten caurinus)* in Kamishak Bay, Alaska. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 252, Juneau.

Hancock, D.A. 1973. The relationship between stock and recruitment in exploited invertebrates. Pages 113-131 in B.B. Parrish, editor. International Council for the Exploration of the Sea, Rapports et Proces-Verbaux des Reunions 164.

Haynes, E.B., and G.C. Powell. 1968. A preliminary report on the Alaska sea scallop - fishery exploration, biology, and commercial processing. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 125, Juneau.

Hennick, D.P. 1970a. The weathervane scallop fishery of Alaska with notes on occurrence in Washington and Oregon. Pacific Marine Fisheries Commission, Annual Report for the Year 1969: 33-34.

Hennick, D.P. 1970b. Reproductive cycle, size at maturity, and sexual composition of commercially harvested weathervane scallops *(Patinopecten caurinus)* in Alaska. Journal of the Fisheries Research Board of Canada 27: 2112-2119.

Hennick, D.P. 1971. A hermaphroditic specimen of weathervane scallop Patinopecten caurinus, in Alaska. Journal of the Fisheries Research Board of Canada 28:608-609.

Hennick, D.P. 1973. Sea scallop, *Patinopecten caurinus*, investigations in Alaska. Alaska Department of Fish and Game, Division of Commercial Fisheries, Completion Report 5-23-R, Juneau.

Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. Fishery Bulletin 82(1): 898-902.

Hudgins, S. 1981. New threats from PSP. Sea Grant Today 11(3):3.

Kaiser, R.J. 1986. Characteristics of the Pacific weathervane scallop *(Pecten [Patinopecten] caurinus,* Gould 1850*)* fishery in Alaska, 1967-1981. Alaska Department of Fish and Game, Division of Commercial Fisheries (Unpublished Report, Catalog RUR-5J86-01), Juneau.

Kessler, D.W. 1985. Alaska's Saltwater Fishes and Other Sea Life, a Field Guide. NMFS Kodiak Laboratory, Alaska Northwest Publishing Co., Anchorage, Alaska, 358 p.

Klein, D.H., and E.D. Goldberg. 1970. Mercury in the marine environment. Env. Sci. Tech. 4(9):765-768.

Kruse, G.H. 1994. Fishery Management Plan for Commercial Scallop Fisheries in Alaska. ADF&G

Draft Special Publication No. 5.

Larsen, P.F., and R.M. Lee. 1978. Observations on the abundance, distribution, and growth of postlarval sea scallops, Placopecten magellanicus, on Georges Bank. The Nautilus 92:112-115.

Leaman, B.M. 1991. Reproductive styles and life history variables relative to exploitation and management of Sebastes stocks. Environmental Biology of Fishes 30:253-271.

Leibovitz, L., Schott, E.F., and R.C. Karney. 1984. Diseases of wild, captive, and cultured scallops. In: J.M. Capuzzo (Ed), Bay scallop fishery: Problems and management. Woods Hole Oceanographic Institution Tech. Rep. 84-38, pp. 8

Lewbel, G.S. (ed.). 1983. Bering Sea Biology: An evaluation of the environmental data base related to Bering Sea oil and gas exploration and development. LGL Alaska Research Associates, Inc., Anchorage, Alaska, and SOHIO Alaska Petroleum Company, Anchorage, Alaska, IV +180 pp.

MacDonald, B.A., and N.F. Bourne. 1987. Growth, reproductive output, and energy partitioning in weathervane scallops, *Patinopecten caurinus*, from British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 44: 152-160.

McGarvey, R., FF.M. Serchuk, and I.A. McLaren. 1993. Spatial and parent-age analysis of stock recruitment in the Georges Bank sea scallop (Placopecten magellanicus) population. Canadian Journal of Fisheries and Aquatic Sciences 50:564-574.

McLoughlin, R.J., P.C. Young, R.B. Martin, and J. Parslow. 1991. The Australian scallop dredge: estimates of catching efficiency and associated indirect fishing mortality. Fisheries Research 11: 1-24.

Mearns, A.J. and Young, D.R. 1977. Chromium in the marine environment. In: C.S. Giam (Ed), Pollutant effects on marine organisms. Lexington Books: Lexington, MA pp.43-44.

Medcof, J., and N. Bourne. 1964. Causes of mortality of the sea scallop *Placopecten magellanicus*. Proceedings of the National Shellfish Association 53: 33-50.

Murphy, G.I. 1967. Vital statistics of the Pacific sardine (Sardinops caerulea) and the population consequences. Ecology 48:731-736.

Murphy, G.I. 1968. Pattern in life history and the environment. American Naturalist 102:391-403.

NEFMC (New England Fishery Management Council). 1982. Fishery management plan, final environmental impact statement, regulatory impact review for Atlantic sea scallops *(Placopecten magellanicus)*. New England Fishery Management Council, Saugus, Massachusetts.

NEFMC (New England Fishery Management Council). 1993. Final Amendment #4 and Supplemental Environmental Impact Statement to the Atlantic Sea Scallop Fishery Management Plan. New England Fishery Management Council, Saugus, Massachusetts. July 1993.

NPFMC (North Pacific Fishery Management Council). 1989. Fishery Management Plan for the

Commercial King and Tanner Crab Fisheries in the Bering Sea/Aleutian Islands. January 24, 1989.

NPFMC (North Pacific Fishery Management Council). 1990. Environmental assessment for amendment 1 to the fishery management plan for the commercial king and Tanner crab fisheries in the Bering Sea/Aleutian Islands. North Pacific Fishery Management Council, Anchorage, Alaska.

NPFMC (North Pacific Fishery Management Council). 1992. Final Supplemental Environmental Impact Statement and Regulatory Impact Review/Initial Regulatory Flexibility Analysis of Proposed Inshore/Offshore Allocation Alternatives (Amendment 18/23) to the Fishery Management Plans for the Groundfish Fishery of the Bering Sea and Aleutian Islands and the Gulf of Alaska. March 5, 1992.

NPFMC (North Pacific Fishery Management Council). 1994. Stock Assessment and Fishery Evaluation Report(s) for the Groundfish Resources of the Gulf of Alaska, Bering Sea/Aleutian Islands Regions as Projected for 1995. November 1994.

Orensanz, J.M., A.M. Parma, and O.O. Iribarne. 1991. Population dynamics and management of natural stocks. Pages 625-713 in S. E. Shumway, (ed.), Scallops: biology, ecology, and aquaculture. Elsevier, N.Y. 1991.

Otto, R.S. 1981. Eastern Bering Sea crab Fisheries. Pages 1037-1066, In: Hood, D.W., and J.A. Clader (eds.) The Eastern Bering Sea Shelf: Oceanography and Resources. Vol 2. Offshore Marine Pollution Assessment, National Oceanic and Atmospheric Administration (NOAA).

Pesch, G.G. Stewart, N.E., and C. Pesch. 1979. Copper toxicity to the bay scallop (Argopecten irradians). Bull. Environ. Contam. Toxicol. 23(6):769-765.

Peterson, C.H., and H.C. Summerson. 1992. Basin-scale coherence of popoulation dynamics of an exploited marine invertebrate, the bay scallop: implications of recruitment limitation. Marine Ecolocy Progress Series 90:257-272.

Rice, S.D., Moles, A., Taylor, T.L., and J.F. Karinen. 1979. Sensitivity of 39 Alaskan marine species to Cook Inlet crude oil and No. 2 fuel oil. In: Proceedings, Oil Spill Conference 19 Mar 1979, Los Angeles CA (pp 549-554). NOAA/NMFS Auke Bay Lab.

Robert, G., and G.S. Jamieson. 1986. Commercial fishery data isopleths and their use in offshore sea scallop *(Placopecten magellanicus)* stock evaluations. Pages 76-82 *in* G.S. Jamieson and N. Bourne, editors. North Pacific workshop on stock assessment and management of invertebrates. Canadian Special Publication of Fisheries and Aquatic Sciences 92.

Robinson, A.M., and W.P. Breese. 1984. Spawning cycle of the weathervane scallop *Pecten (Patinopecten) caurinus* Gould along the Oregon coast. Journal of Shellfish Research 4: 165-166.

Ronholt, L.L., H.H. Shippen, and E.S. Brown. 1977. Demersal fish and shellfish resources of the Gulf of Alaska from Cape Spencer to Unimak Pass, 1948-1976; a historical review. NOAA/OCSEAP, Final Report. 955 pp.

Rosenberg, A.A., S. Swartz, and G.C. Darcy. 1993. Overview Paper: The scientific basis for definitions of overfishing in the United States. In: A.A. Rosenberg, (Ed.) Defining Overfishing -- Defining Stock Rebuilding. Report of the Second Annual National Stock Assessment Workshop. NOAA Tech. Memo. NMFS-F/SPO-8.

Sharma, D. 1979. The Alaskan shelf. Springer-Verlag, New York. 498 p.

Shumway, S.E. 1990. A review of the effects of algal blooms on shellfish and aquaculture. Journal World Aquaculture Society.

Sinclair, M. 1988. Marine populations: an essay on population regulations and speciation. University of Washington Press, Seattle.

Sinclair, M., R.K. Mohn, G. Robert, and D.L. Roddick. 1985. Consideration for the effective management of Atlantic scallops. Canadian Technical Report of Fisheries and Aquatic Sciences 1382.

Sindermann, C.J. 1979. Environmental stress in oceanic bivalve mollusc populations. Proc. Nat. Shellfisheries Assoc. 69:147-156.

Somerton, D.A. 1981. Life history and population dynamics of two species of Tanner crab, Chionectes bairdi and C. opilio, in the eastern Bering Sea with implications for the management of the commercial harvest. Ph.D. Dissertation, Univ. of WA, 220 p.

Starr, R.M., and J.E. McCrae. 1983. Weathervane scallop (Patinopecten caurinus) investigations in Oregon, 1981-1983. Oregon Department of Fish and Wildlife, Information Reports 83-10, Newport.

Tremblay, M.J., and M. Sinclair. 1992. Planktonic sea scallop larvae (Placopecten magellanicus) in the Georges Bank region: broadscale distribution in relation to physical oceanography. Canadian Journal of Fisheries and Aquatic Sciences 49:1597-1615.

Vattuone, G.M., Griggs, K.S. McIntire, D.R., Littlepage, J.L., and F.L. Harrison. 1976. Cadmium concentrations in rock scallops in comparison with some other species. Lawrence Livermore National Laboratory, UCRL-52022. 31 pp.

Wassman, R., and J. Ramus. 1973. Seaweed invasion. Natural History 82(10):25-36.